W/Z Production at the LHC and the Parton Distribution Functions

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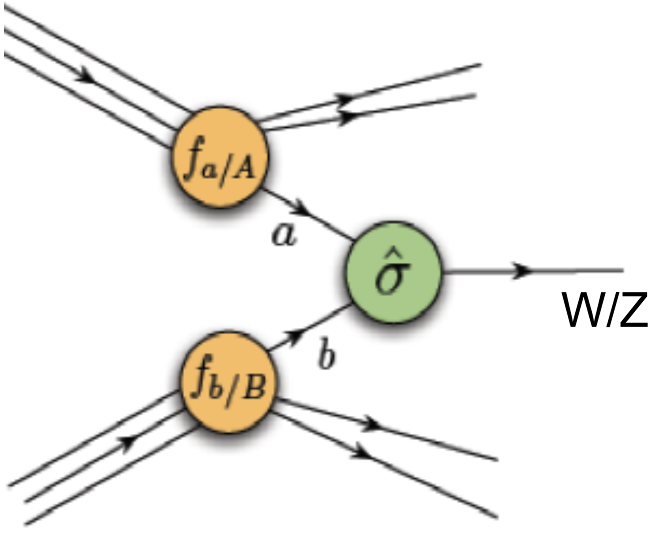
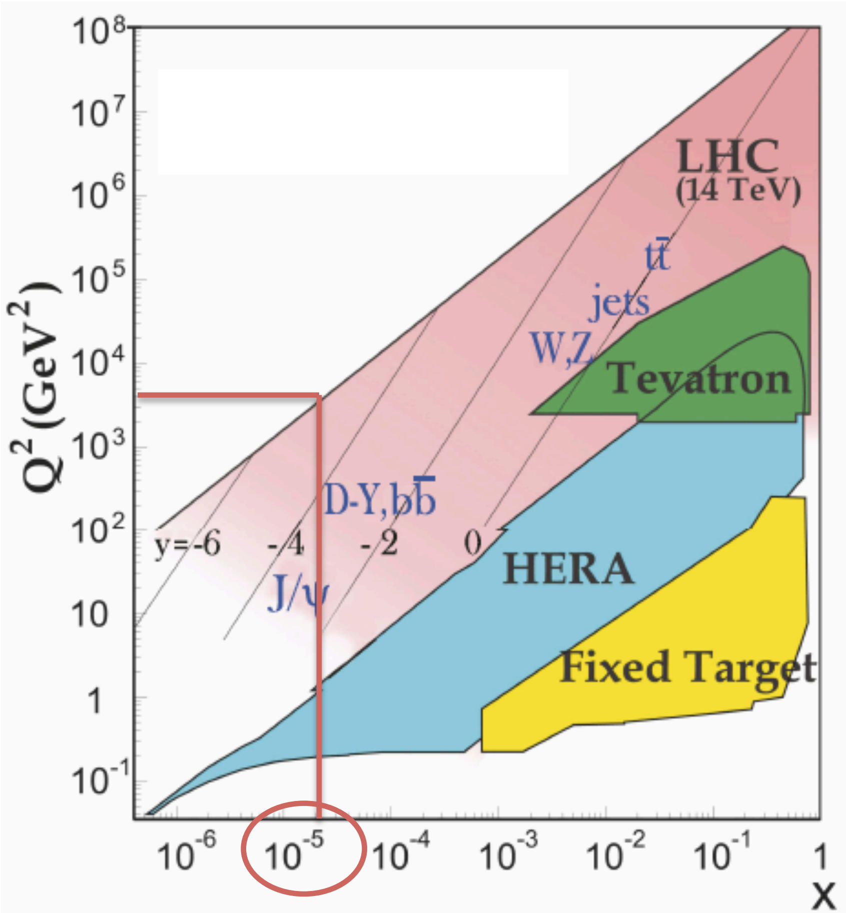
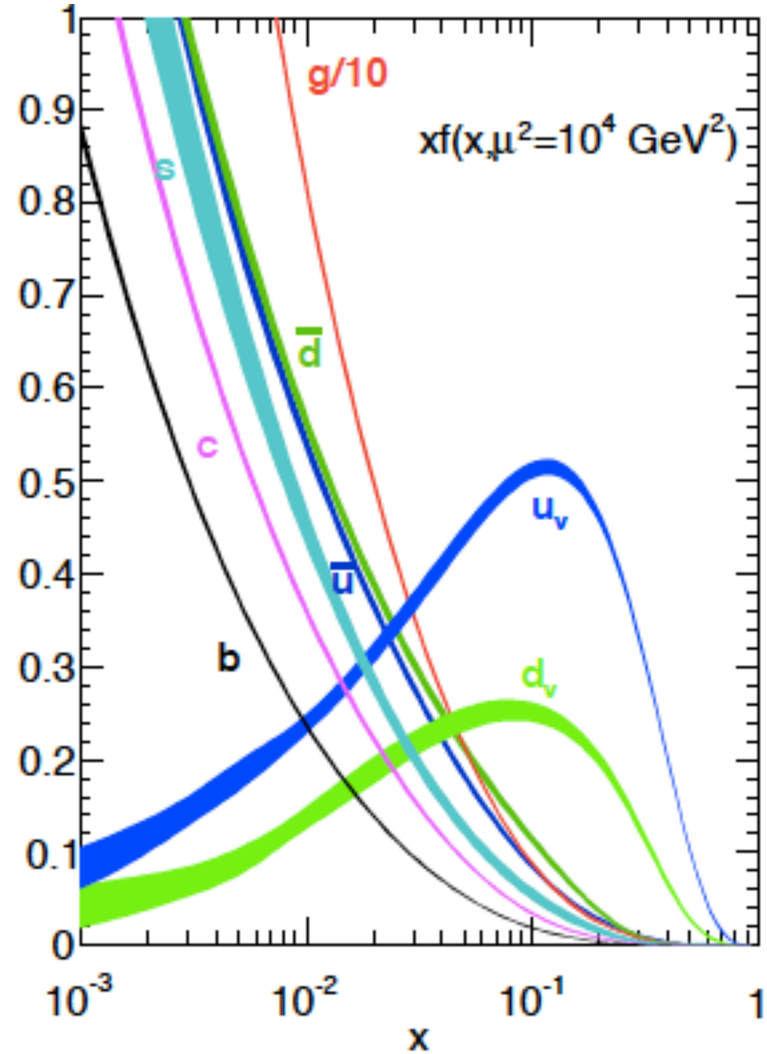
W and Z Production

- W/Z bosons are produced abundantly from the Drell-Yan process.
- This process has contributed to the precise measurement of the standard model parameters.
- Higher order QCD corrections can be tested with the W/Z production cross sections.
- The rapidity distribution of W/Z cross sections can be used to determine the parton distribution functions (PDF) of the proton.

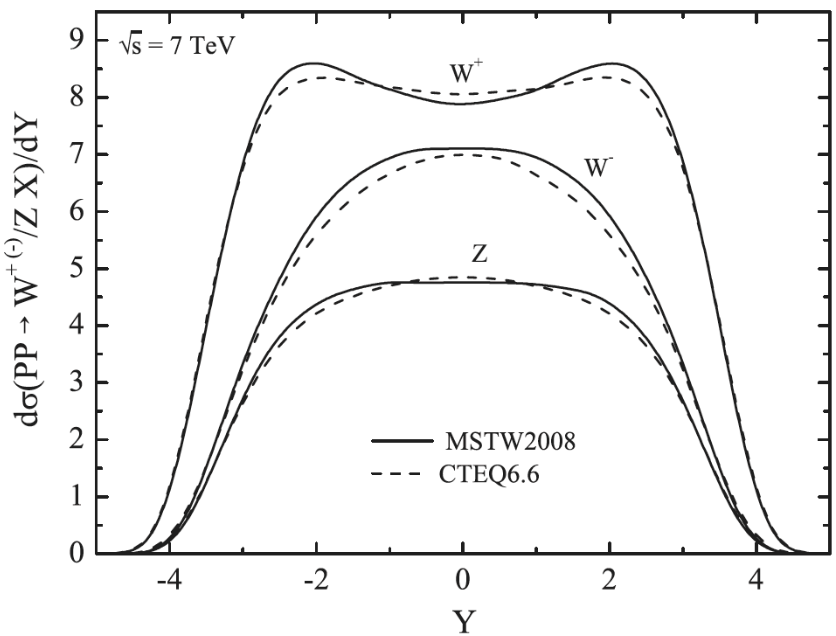


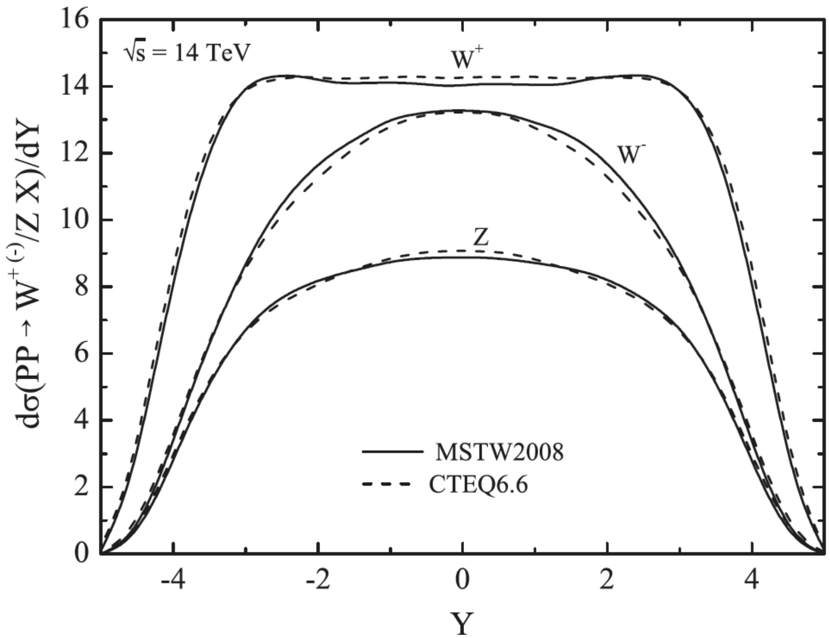




$$x_{A/B} = \frac{M_{W/Z}}{\sqrt{s}} e^{\pm y}$$

Rapidity distribution of cross sections - dσ/dY



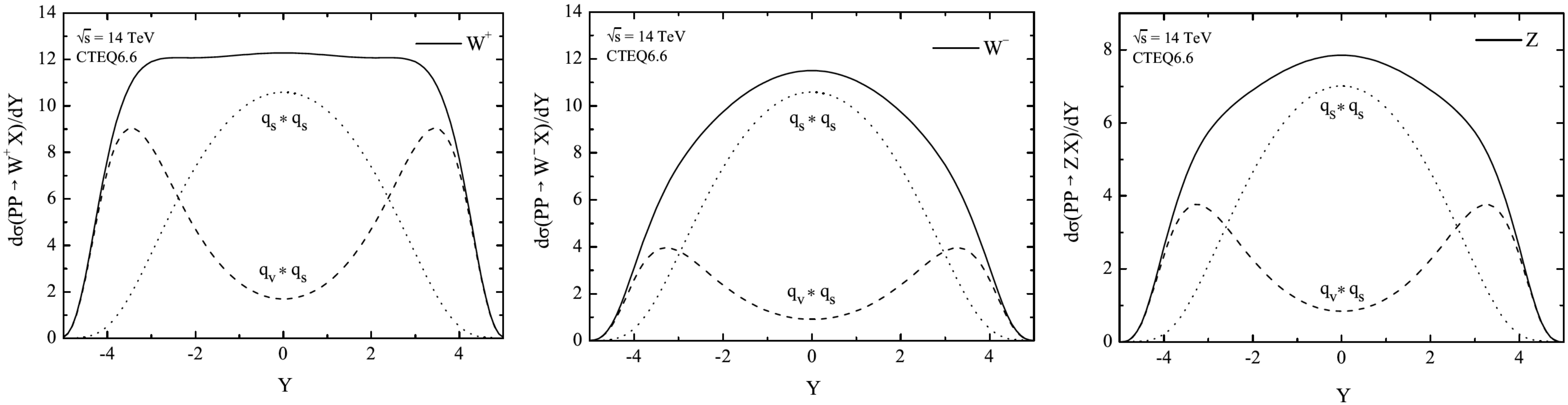


- $\frac{d\sigma}{dy}(Y) = \frac{d\sigma}{dy}(-Y)$

- Accessible range: $|Y| \leq 4.3$ at 7 TeV $\rightarrow\ x \sim 2\times10^{-4}$

  $|Y| \leq 5$ at 14 TeV $\rightarrow\ x \sim 4\times10^{-5}$

Sea quark contributions to dσ/dY



- Sea-sea contributions to W^+ and W^- are the same.

- Sea-sea contribution dominates at the central rapidity region, while the valence-sea interaction contributes more to the forward/backward regions.

- As energy increases, the relative contribution of sea-sea interaction becomes more important.
  - e.g.) W+: 75% at 7 TeV -> 86% at 14 TeV

W Charge Asymmetry, A(Y)

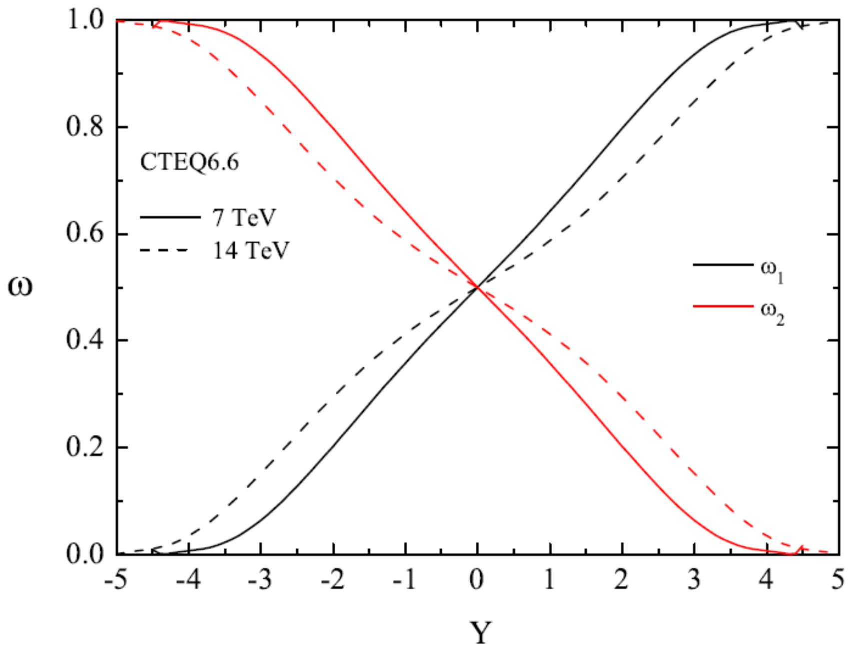
$$A(Y) \equiv \frac{d\sigma_{W^+}/dY - d\sigma_{W^-}/dY}{d\sigma_{W^+}/dY + d\sigma_{W^-}/dY}$$

- The sea-sea contributions to W+ and W- are the same.
- Small CKM matrix elements except V_{ud}:
  - $(V_{ud})^2 = \sim 0.95$, $(V_{us})^2 = \sim 0.05$, $(V_{ub})^2 \sim 10^{-5}$

➔ The W charge asymmetry is the approximate result of the difference in the u and d distributions.

W Charge Asymmetry, A(Y)

$$A(Y) \approx \left\{ w_1 \frac{u(x_1)-d(x_1)}{u(x_1)+d(x_1)} + w_2 \frac{u(x_2)-d(x_2)}{u(x_2)+d(x_2)} \right\}$$

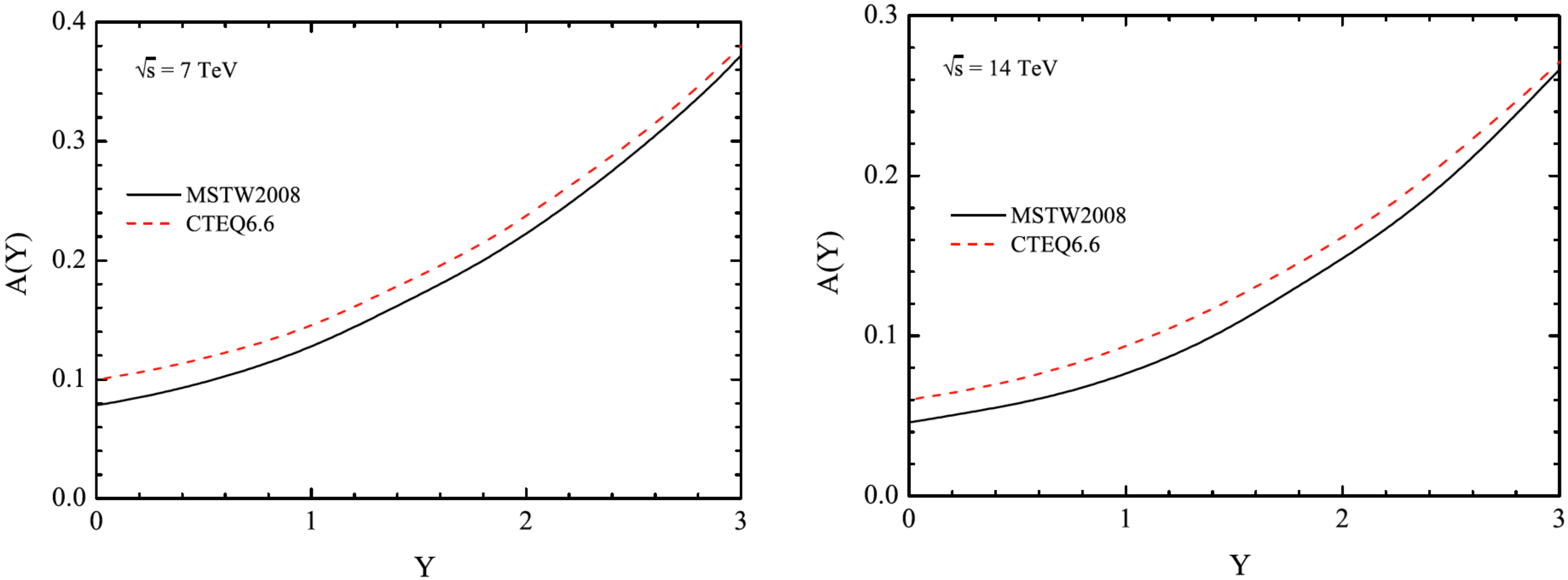


$$\omega_1 \equiv \frac{\dfrac{\bar{u}(x_2)-\bar{d}(x_2)}{u(x_2)+d(x_2)}}{\left[\dfrac{\bar{u}(x_1)-\bar{d}(x_1)}{u(x_1)+d(x_1)} + \dfrac{\bar{u}(x_2)-\bar{d}(x_2)}{u(x_2)+d(x_2)}\right]}$$

$$\omega_2 \equiv \frac{\dfrac{\bar{u}(x_1)-\bar{d}(x_1)}{u(x_1)+d(x_1)}}{\left[\dfrac{\bar{u}(x_1)-\bar{d}(x_1)}{u(x_1)+d(x_1)} + \dfrac{\bar{u}(x_2)-\bar{d}(x_2)}{u(x_2)+d(x_2)}\right]}$$

$$A(0) \approx \frac{u(x)-d(x)}{u(x)+d(x)}$$

W Charge Asymmetry



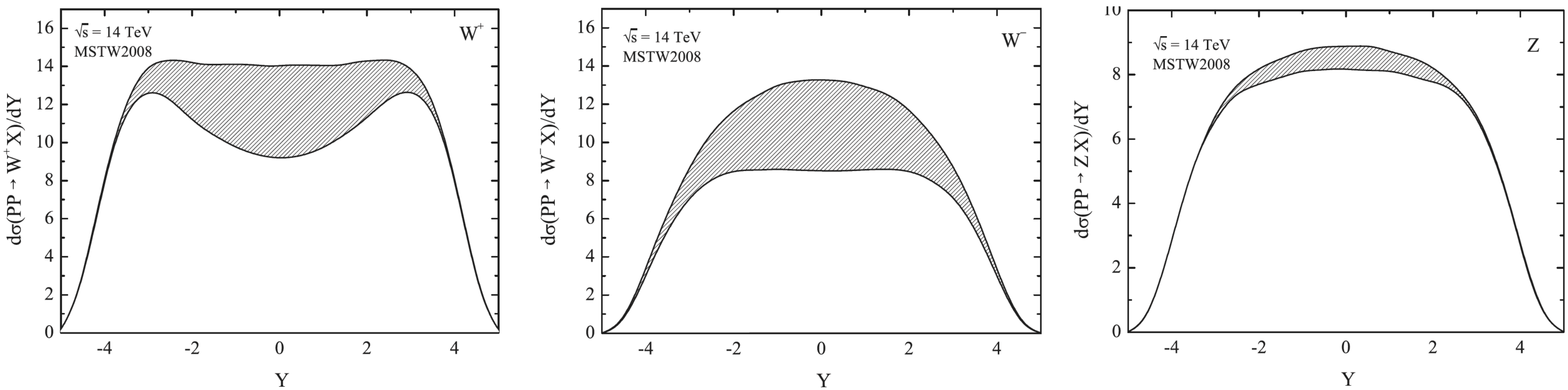
- There is about 20% difference between CTEQ6.6 and MSTW2008.

- A(Y) becomes smaller at higher energy due to small difference between u and d distributions at lower x.

Charm Quark Distributions

$$B(Y) \equiv \frac{d\sigma_{W^+}/dY + d\sigma_{W^-}/dY}{d\sigma_z/dY}$$

Charm-quark contributions to dσ/dY

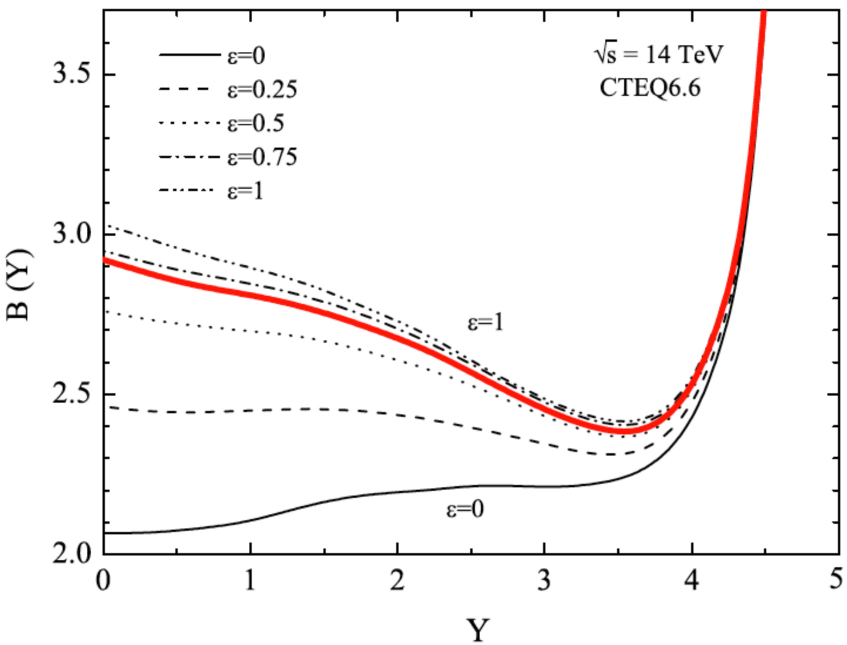


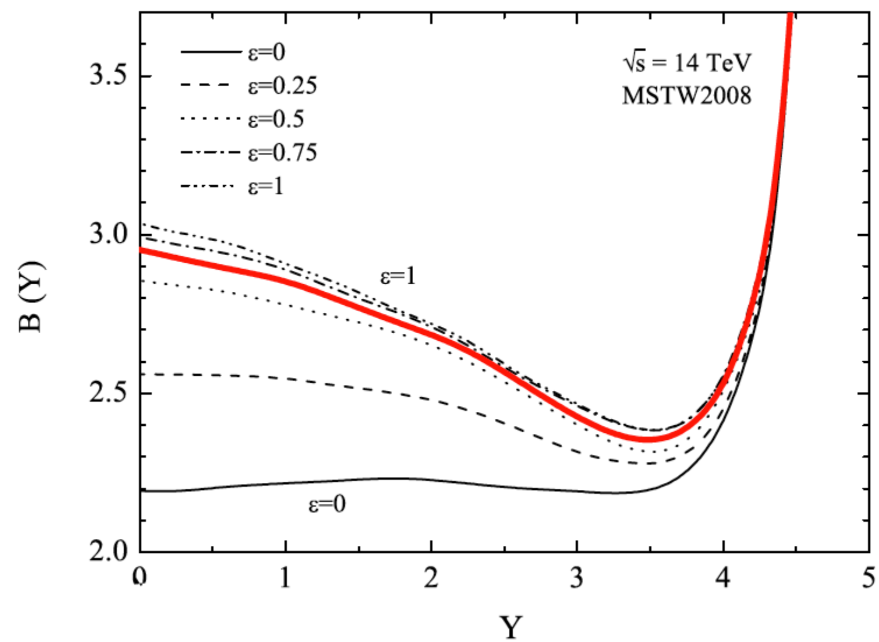
- The shaded area indicates the charm contributions.
- Like the sea contribution case, the charm contribution increases with the collision energy.

  At Y=0, (27%, 29%, 6%) for (W+, W-, Z) at 7 TeV

  (34%, 36%, 8%) at 14 TeV.

$$B(Y) \equiv \frac{d\sigma_{W^+}/dY + d\sigma_{W^-}/dY}{d\sigma_z/dY}$$

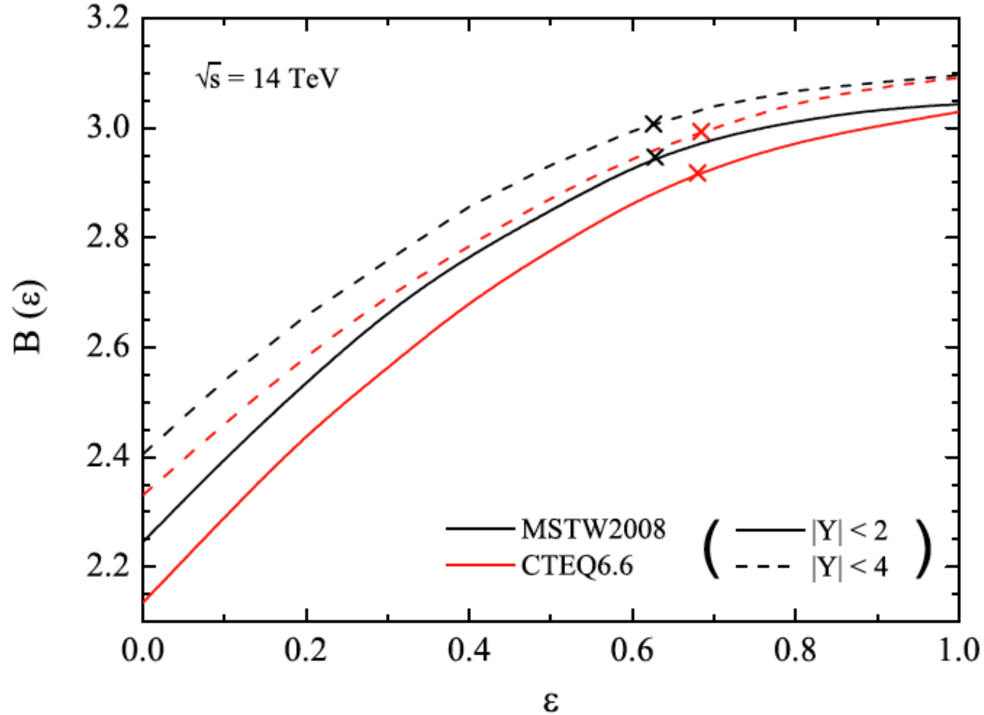




$$\varepsilon \equiv \frac{c(x)}{(\bar{u}(x) + \bar{d}(x))/2}$$

- The value of ε for both CTEQ6.6 and MSTW2008 PDF is between 0.5 – 0.75.

$$B(\varepsilon) = \int_{|Y|<i} \frac{d\sigma_{W^+}/dY + d\sigma_{W^-}/dY}{d\sigma_z/dY_z}$$



- The quantity ε is about 0.7 for CTEQ6.6, and 0.6 for MSTW2008.

Summary

- At the level of LHC energy, the sea quark interactions are considerable. It is essential to explore the parton distributions at the LHC for better prediction of measurable cross sections.

- The charge asymmetry is almost independent from the sea quark contributions. Therefore, it is optimal to investigate the u(x) and d(x) distributions.

- The charm quark distributions can be determined by B(Y) and B(ε) measured or translated from the measurement of W/Z rapidity distributions using $\varepsilon = 2c(x)/(\bar{u}(x)+\bar{d}(x))$.