RADIATIVE CORRECTIONS FOR DEEP INELASTIC SCATTERING IN THE PRESENCE OF AN ADDITIONAL $Z'$

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1. INTRODUCTION
2. METHOD OF CALCULATION
3. NUMERICAL RESULTS
   • $\delta_{NC} = \frac{\sigma_{NC}^{\text{Born}+1L}}{\sigma_{NC}^{\text{Born}}} - 1$
   • $A_{LR,SM}^{\text{Born}+1L}$ VS. $A_{LR,SM}^{\text{Born}+1L}$
4. CONCLUSIONS
\[ L = e A_\mu J^\mu_y + g_1 Z_\mu J^\mu_z + g_2 Z_\mu J^\mu_x \]

\[ J^\mu_y = \sum_f \bar{f} \gamma_\mu [\gamma^5 + \gamma^\alpha (f)] f \]

\[
\begin{pmatrix}
Z_1 \\
Z_2 \\
\end{pmatrix} =
\begin{pmatrix}
\cos \theta_\text{M} & \sin \theta_\text{M} \\
-\sin \theta_\text{M} & \cos \theta_\text{M} \\
\end{pmatrix}
\begin{pmatrix}
Z \\
Z' \\
\end{pmatrix}
\]

\[ \tan^2 \theta_\text{M} = \frac{M_2^2 - M_1^2}{M_2^2 - M_z^2} \]

Here: \( \cos \theta_\text{M} \to 1 \)

**CONSIDER:**

\[ E_6 \longrightarrow SU_{3C} \otimes SU_{2L} \otimes U_{1Y} \otimes U_{1X} \otimes U_{1Y} \]

QCD \quad EWTHY \quad Z'-BOSONS

\[ Z' = \cos \theta_\text{E} Z'_x + \sin \theta_\text{E} Z'_\psi \]

**3 CASES:**

A: \[ Z'_i = \sqrt{\frac{3}{8}} Z'_x - \sqrt{\frac{5}{8}} Z'_\psi \]

B: \[ Z'_x \]

C: \[ Z'_\psi \]

BINETRUY et al.

ELLIS et al. '86
• RC to $a_T$ may be large
• As large or larger than $Z'$-effects
• Calculate: QED + Loop contributions
2. METHOD OF CALCULATION

CORRECTIONS COME FROM:

1) BREMSSTRAHLUNG OF PHOTONS (QED)

2) STANDARD ELECTROWEAK LOOP CORRECTIONS AND RUNNING \( \alpha_{\text{QED}} \)

3) LOOP CORRECTIONS: \( Z^1 \) EXCHANGE & EXTENDED HIGGS SECTOR (WILL BE IGNORED, BECAUSE ARE SMALL)

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1) QED - BREMSSTRAHLUNG:


\[
\frac{d^2 \sigma_{\text{Born}}}{dx dy} = \frac{2\pi \alpha^2 S}{Q^4} \left[ \sigma_{\gamma \gamma} + \sigma_{\gamma Z} + \sigma_{Z Z} + \sigma_{Z Z'} + \sigma_{Z' Z} \right]
\]

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\( B = \gamma, Z, Z^1 \) - COLL. EMISSION

RELEVANT DIAGRAMS
\[
\frac{d\sigma^{\text{QED}}}{dx\,dy} = \frac{\alpha}{2\pi} \ln\left(\frac{Q^2}{m_e^2}\right) \left\{ \frac{1}{1+z} \left[ \frac{\Theta(z-2z')}{y} \frac{1}{z} \frac{d\sigma^B}{dx\,dy} \right] \right. \\
\left. - \left. \frac{d\sigma^B}{dx\,dy} \right\} \\
+ \frac{\alpha^3}{8\pi} \frac{Q^4}{\Lambda^2} \int dz \frac{1}{2z} \sum_i e_i^2 z(q(z,a^2) + \bar{q}(z,a'^2)) \\
\cdot \frac{z^2 + (x-z)^2}{x(1-y)} \left[ 1 + (1-y)^2 \right]
\]
\[
\frac{d\sigma^B}{dx\,dy} = \frac{d\sigma^{\text{Born}}}{dx\,dy}(y, z, z') \\
\hat{x} = \hat{x}(z), \hat{x}(z_0) = 1 \\
\hat{y} = \frac{z+y-1}{z} \\
\text{INITIAL STATE RADIATION:} \\
a = 1, \; \hat{x} = xy z/(z+y-1), \; \hat{s} = z \hat{s} \\
\text{FINAL STATE RADIATION:} \\
a = 2, \; \hat{x} = xy/(z+y-1), \; \hat{s} = s/z
\]

2) EIN- CORRECTIONS

Bardin, Hollik, Riemann, MPI-PAE/PTH 32/9
PHE 90-09

\[ G_\mu \rightarrow G_\mu \cdot q(\alpha, M_2, M_H, m_t, \ldots) \]
\[ \sin^2\theta_W \rightarrow \sin^2\theta_W \cdot \mathcal{E}(\alpha, M_2, M_H, m_t, \ldots) \]
\[ \mathcal{E}_e, \mathcal{E}_q, \mathcal{E}_{eq} = \mathcal{E}(s, \xi^2, \text{flavour}) \]
3. NUMERICAL RESULTS

1) RELATIVE CORRECTION TO THE CROSS SECTION:

\[ \delta_{NC} = \frac{d^2\sigma_{X,Z,Z'}^0}{dx\,dy} / \frac{d^2\sigma_{X,Z,Z'}^0}{dx\,dy} - 1 \]

COMPARE: SM vs. SM + Z'

NEARLY UNCHANGED: \( M_{Z'} = 300 \text{ GeV} \), MODEL A.

SIMILAR: MODEL B, C.

⇒ RC TO \( \frac{d\sigma}{dx\,dy} \) CAN BE CARRIED OUT IN THE WAY AS IN SM EVEN IF THERE IS A Z'! (WE NEED THIS NOT TO KNOW BEFOREHAND.)

2) SEARCH FOR Z' VIA A_{LR}:

\[ L/R = \lambda = -1/0.8 \]

\[ A_{LR} = \frac{\frac{d^2\sigma^-}{dx\,dy} (\lambda = -.8)}{\frac{d^2\sigma^-}{dx\,dy} (\lambda = -.8) + \frac{d^2\sigma^-}{dx\,dy} (\lambda = +.8)} \]
\[ \frac{\text{Sigma(corr)}}{\text{Sigma(Born)}} - 1 \]

\[ s = 4 \times 10000 \times 100 \text{ GeV} \]

\[ m^2 = 300 \text{ GeV} \]

\[ x \approx 0.9 \quad x \approx 0.5 \quad x \approx 0.1 \]
We discuss the models A, B, C for LEP2 x LHC and $M_{Z'} = 300 \& 500$ GeV.

Compare: $A_{LR}^{-(0+1l)}_{\text{SM}}$ vs. $A_{LR}^{-(0+1l)}_{\text{SM}+Z'}$

- $Z'$ effect diminishes from A $\rightarrow$ C for $M_{Z'} = \text{const}$.
- Dimin. with growing $M_{Z'}$. (Comp. $M_{Z'} = 300 \text{ GeV}$ $M_{Z'} = 500 \text{ GeV}$)

$\Rightarrow$ RC's have to be considered to determine $Z'$ effects
- Sizeable effects on $(x_{1y})$ - dependence of $A_{LR}^{-}$.
Left–Right–Asymmetry (e–)

$m_z = 300 \text{ GeV}$

degree of polarization $= 0.8$

Model A ($Z'$)

$x = 0.5$

$x = 0.9$

$x = 1.0$

$x = 0.1$

$s = 4 \times 8000 \times 100 \text{ GeV}$
Left-Right-Asymmetry (e-)

\( s = 4 \times 8000 \times 100 \text{ GeV} \)

\( m_z = 300 \text{ GeV} \)

Model B \((Z^0)\)

Degree of Polarization = 0.8

\( y \)

\( x \)
Left–Right–Asymmetry (e–)

\[ s = 4 \times 8000 \times 100 \text{ GeV} \]

\[ m^2 = 500 \text{ GeV} \]

Model B (Z(\chi))

Degree of Polarization = 0.8

\[ y = 0.5 \]

\[ y = 0.9 \]
Left-Right-Asymmetry (e−)

\[ s = 4 \times 8000 \times 100 \text{ GeV} \]
\[ m_z = 300 \text{ GeV} \]
Model C \( (Z^0) \)
degree of polarization = 0.8
4. CONCLUSIONS

1) QED & LOOP CORR. (BM) FOR

\[ \text{ep} \rightarrow \text{ex}(\gamma) \]

INCLUDING \( Z' \) EFFECTS HAVE BEEN CALCULATED FOR SOME MODELS (A, B, C).

2) \( \delta_{\text{NC}} \) REMAINS NEARLY UNCHANGED, IF SM VS. SM+\( Z' \) IS COMPARED:
   i.e. ONE MAY FIND \( Z' \) EFFECTS CORRECTLY IN GOOD APPROXIMATION EVEN IF SM RC'S ARE APPLIED TO \( d\sigma/dx dy \).

3) THE INFLUENCE OF THE RC'S ON THE \((x,y)\) DEPENDENCE OF \( A_{\ell\ell'}(a=1,2) \) IS RATHER STRONG. THE \( Z' \) EFFECT IS AFFECTED COMPARED TO \( A_{\ell\ell'} \) STRONGEST FOR MODEL (A > B > C). THE EFFECT IN \( A_{\ell\ell'}(0.41 \text{GeV}) \) DIMINISHES WITH GROWING \( m_{Z'} \).