PROCEEDINGS OF SCIENCE

Applicability of the formulae of Bardin and Dokuchaeva for the radiative corrections analysis in the NuTeV experiment

Arif Akhundov[*†]
Institute of Physics, Azerbaijan Academy of Sciences,
H. Cavid ave. 33, Baku 370143, Azerbaijan
E-mail: Arif.Akhoundov@cern.ch

We point out one of the possible sources of the "NuTeV anomaly": the effect of the non-adequate application of the one-loop electroweak radiative corrections including QED hard photon emission derived by Bardin and Dokuchaeva (1986) in the NuTeV radiative corrections data analysis of deep inelastic neutrino and anti-neutrino deep inelastic scattering.

10th International Workshop on Neutrino Factories, Super beams and Beta beams
June 30 - July 5 2008
Valencia, Spain

[*]Speaker.
[†]Present address: HBCC, King Fahd University of Petroleum and Minerals, Hafr Al-Batin 31991, Saudi Arabia

© Copyright owned by the author(s) under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike Licence.

PoS(NuFact08)115

Here we point out one of the possible sources of the "NuTeV anomaly" [1]: the effect of the non-adequate application of the Fortran program NUDIS [2] for the calculations of the electroweak RC to the inclusive cross section of deep inelastic $\nu_\mu(\bar{\nu_\mu})N$-scattering in the data analysis of neutrino and anti-neutrino DIS in the NuTeV experiment. This effect we consider as the most promising [3] that might reconcile the NuTeV measurement with the precise measurements near the Z pole.

The main contribution to the total RC arises from δR^{ν}_{CC} [2, 4, 5, 6], i.e. from the charged current events in the neutrino DIS:

$$\nu_\mu + N \to \mu^- + X. \tag{1}$$

The electroweak RC to DIS have two different parts - weak RC and QED RC. The contribution of the weak RC does not depend from the event selection in the experiment, but the contribution of the QED RC depends significantly on the measured kinematical quantities: the radiative corrections calculated in a different set of variables can have a completely different value and behavior [7] because of the different bremsstrahlung contribution to (1) from the process:

$$\nu_\mu + N \to \mu + X + \gamma. \tag{2}$$

with non-observed photon(s).

The general formula [7] for the radiatively corrected neutrino DIS cross section in terms of leptonic variables can be represented as the sum of the Born distribution with the contributions due to virtual loop diagrams and real hard photon emission:

$$\frac{d^2\sigma^{RC}}{dxdQ^2} = \frac{d^2\sigma^{Born}}{dxdQ^2}\,(1\,+\,\delta^V(x,Q^2)) + \int\!\!\int dx_h dQ_h^2\, H(x,Q^2,x_h,Q_h^2)\,\frac{d^2\sigma^{Born}}{dx_h dQ_h^2} \tag{3}$$

The part of (3) proportional to $\delta^V(x,Q^2)$ contains the contributions from the EW and QED loop corrections and from the soft part of the real photon radiation. The second part accounts for the bremsstrahlung contribution (2) where the function $H(x,Q^2,x_h,Q_h^2)$ is the hard photon radiator.

The explicit formulae for $\delta^V(x,Q^2)$ and $H(x,Q^2,x_h,Q_h^2)$ are derived in [2] in the framework of the quark-parton model and in the approximation of the four-momentum contact interaction neglecting the terms of the order $\alpha Q^2/M_W^2$. Moreover, in [2] for the density function of the initial quark in the nucleon $f_i(x,Q)$ the scaling approximation is used which simplifies the calculation of the twofold integral in (3).

The NuTeV experiment uses [8] the computer program ZFITTER [9] for the calculation of the electroweak corrections and the formulae of Bardin and Dokuchaeva [2] implemented in the Fortran program NUDIS [2] which contains the virtual loop corrections and the bremsstrahlung contributions of the order $\mathscr{O}(\alpha)$ to the inclusive differential cross section $d^2\sigma/dxdQ^2$ of neutrino and anti-neutrino CC and NC DIS in leptonic variables at fixed energy of the neutrino beam and without applying any cut on photon kinematics. [1]

In reality the initial energy of neutrino E_ν is measured for *each selected event*. In the NuTeV [8] the three experimentally measured quantities are: E_μ and θ_μ, the energy and the scattering angle

[1] With the exception of a cut on the energy of final hadrons $E_h > 10\ GeV$.

PoS(NuFact08)115

of the outgoing muon, and E_{HAD}, the energy deposited in the target calorimeter which includes the energy of the hadronic final state E_h and the energy of the emitted photon E_γ:

$$E_{HAD} = E_h + E_\gamma. \tag{4}$$

The measurement of E_{HAD} for the event selection [8] means the detection of real hard photons with the energy $E_\gamma > \bar{E}_\gamma$, where $\bar{E}_\gamma$ is the photonic calorimeter threshold.

Therefore, the contribution of such hard photons to the inclusive cross section of DIS should be subtracted from the bremsstrahlung integral in (3). This implies the integration in (3) over the physical region (x_h, Q_h^2) [7] restricted by the following condition:

$$Q_h^2/x_h \geq Q_l^2/x_l - 2M\bar{E}_\gamma \tag{5}$$

This is the main point of the non-adequate application of the formulae of Bardin and Dokuchaeva and the Fortran program NUDIS in the radiative corrections analysis of the NuTeV experiment.

Acknowledgments

I would like to thank the organizers of the NuFact08 Workshop for kind hospitality. I thank K. McFarland, Y. Hayato and A. Blondel for the discussions. I am grateful to P. Hernandez and N. Rius for support and to A. Shiekh for remarks.

References

[1] NuTeV Collaboration, G. P. Zeller, et al., *A Precise determination of electroweak parameters in neutrino nucleon scattering*, *Phys. Rev. Lett.* **88** 091802 (2002); Erratum-ibid. **90** 239902 (2003) [hep-ex/0110059].

[2] D. Yu. Bardin and V. A. Dokuchaeva, *On the radiative corrections to the neutrino deep inelastic scattering*, Preprint JINR-E2-86-260, Dubna (1986).

[3] Arif Akhundov, *Precision Tests of Electroweak Interactions*, *AIP Conf. Proc.* **1006** 43 (2008) [hep-ph/0801.4651].

[4] K. P. Diener, S. Dittmaier and W. Hollik, *Electroweak radiative corrections to deep inelastic neutrino scattering: Implications for NuTeV?*, *Phys. Rev.* **D69** 073005 (2004) [hep-ph/0310364].

[5] A. B. Arbuzov, D. Yu. Bardin and L. V. Kalinovskaya, *Radiative corrections to neutrino deep inelastic scattering revisited*, *J. High Energy Phys* **JHEP06** 078 (2005) [hep-ph/0407203].

[6] K. P. Diener, S. Dittmaier and W. Hollik, *Electroweak higher-order effects and theoretical uncertainties in deep-inelastic neutrino scattering*, *Phys. Rev.* **D72** 093002 (2005) [hep-ph/0509084].

[7] Arif Akhundov, et al., *Model independent QED corrections to the process e p —> e X*, *Fortsch. Phys.* **44** 373–482 (1996) [hep-ph/9407266].

[8] NuTeV Collaboration, M. Tzanov, et al., *Precise measurement of neutrino and anti-neutrino differential cross sections*, *Phys. Rev.* **D74** 012008 (2006) [hep-ex/0509010].

[9] D. Yu Bardin, et al., *ZFITTER v.6.21: A Semianalytical program for fermion pair production in e+ e- annihilation*, *Comp. Phys. Comm.* **133** 229 (2001) [hep-ph/9908433].

PoS(NuFact08)115