Evaluation of radiative corrections to the e + p → e + p + π^0 reaction studied by coincident detection of e and p

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Abstract

Radiative corrections to the cross sections of the exclusive neutral pion electroproduction are evaluated by employing a code EXCLURAD for the kinematics of the 1st, 2nd and 3d resonance region. Advantages of different approaches to practical implementation of some procedures for radiative corrections is discussed. Possible development of the procedures is suggested.

One of the research topics related to the hadron structure studies concerns the exclusive electroproduction of π^0 in the $e+p \to e+p+\pi^0$ reaction [1]. In the present form of the data analysis, the measured differential cross sections $\sigma_{\rm meas}$ are converted into the cross sections σ_0 corresponding to the one photon approximation following the procedure developed for the calculation of the radiative corrections to the $e + p \to e + p + \gamma$ reaction [2]. Below I comment on the possibility of employing an alternative procedure, which became recently available as a software code EXCLURAD [3, 4]. This code computes radiative corrections to the four-fold differential cross section $d^4\sigma/dWdQ^2d\cos\theta d\phi_h$. The latter is calculated within a realistic model describing exclusive pion electroproduction in the three resonance regions — $1100 < W < 1900$ MeV, for instance in the framework of the unitary isobar model MAID2000 [5].

The radiative correction factor is defined in ref. [3] as

$$\delta \;=\; \frac{\sigma_{\rm meas}}{\sigma_0}\;, \tag{1}$$

where σ_0 is the meson electroproduction cross section evaluated in the Born approximation (by employing e.g. code MAID2000), and $\sigma_{\rm meas}$ models the observed cross section in the coincidence measurements of the outgoing electron and a charged hadron (pion or proton). The observed (measured) cross section is represented as a combined contribution from several mechanisms of the photon radiation:

$$\sigma_{\rm meas} = \sigma_0 e^{\delta_{\rm inf}}(1 + \delta_{\rm VR} + \delta_{\rm vac}) + \sigma_{\rm F}\;. \tag{2}$$

Here the partial corrections $\delta_{\rm inf}$ and $\delta_{\rm vac}$ take into account radiation of *soft photons* and effects of *vacuum polarization*, and the correction $\delta_{\rm VR}$ is an infrared-free sum of factorized parts of *real* and *virtual* photon radiation, and $\sigma_{\rm F}$ is an infrared-free contribution from the *bremsstrahlung process.*

As long as some part of the measured energy of the secondary particles is missing due to the unobserved irradiated photons, the region of integration considered in the evaluation of the different contributions depends on the missing mass (or inelasticity of the reaction). It is defined in ref. [3] as

$$v = W^2 + m_h^2 - m_u^2 - 2WE_h \ , \tag{3}$$

where subscripts u and h are used to define parameters of the unobserved and detected hadron, respectively. Maximal value of v corresponds to the threshold of the pion electroproduction, and, therefore, to the maximal energy carried away by bremsstrahlung photons. Figure 1 displays parameter v as a function of W for two electroproduction reactions. EXCLURAD uses v as an input parameter in order to restrict limits of integration by the value of the missing mass cut employed in the event selection procedure.

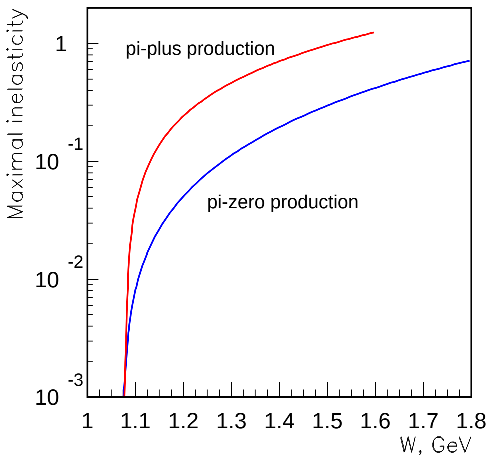

Figure 1: Maximum inelasticity in units of GeV^2 as a function of W evaluated for two different cases of the detection of the outgoing hadron: pion (upper line) or proton (lower line).

According to the results which I have obtained by using EXCLURAD, the radiative correction is a non-trivial function of W. It is compared in Figure 2 with the W independent factor $\delta_R = 0.931 \pm 0.030$, which is currently used to account for the real internal radiative effects in data analysis at the final stage. Of course, the comparison is not complete, because one part of the real internal radiative effects, which is a function of the event selection cut applied on the right side of the missing mass squared distribution $x_r \equiv M_X^2|_{\rm max}$, is simulated by the Monte Carlo code [6]. Such separation of the real internal radiative effects into two parts can not be realized with the current version of EXCLURAD.

The non-trivial W dependence of the radiative correction has to be attributed to the last term of Eq.(2). It is demonstrated by the dashed line in Figure 2, which was obtained by dropping last term $\sigma_{\rm F}$ from Eq.(2). The effect of the inelasticity cut is clearly seen as a bend in the dashed line at $W \approx 1.2$ GeV, which corresponds to $v = 0.05$ GeV^2.

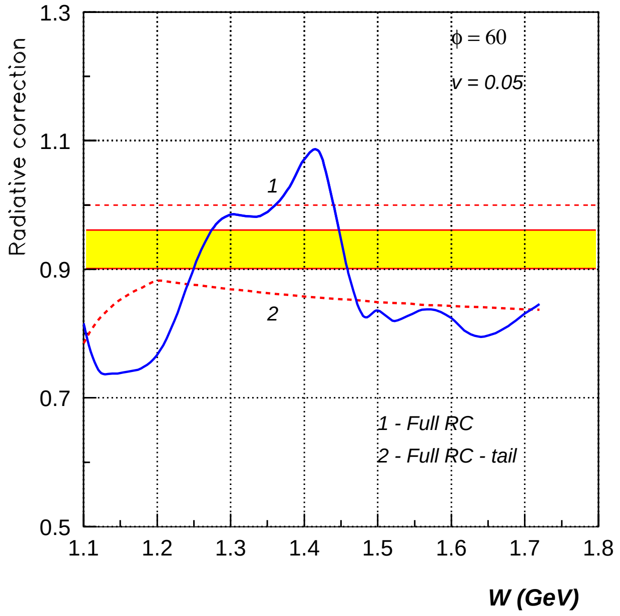

Figure 2: Radiative corrections evaluated as a function of W by including all radiative processes - full line, and by leaving out contribution of the radiative tail - dashed line. The two results are obtained with the inelasticity cut v =0.05 GeV^2. Shaded area corresponds to the W-independent correction δ= 0.931 $\pm$0.030 .

I find that at certain values of W, the contribution from the radiative tail described by the term $\sigma_{\rm F}$ changes considerably ϕ dependence of the correction. This is particularly the case for the high W range (see Figure 3). It is worth mentioning that the inelasticity cut changes not only absolute value of the correction but the ϕ dependence of the correction as well. The effect is shown in Figure 4.

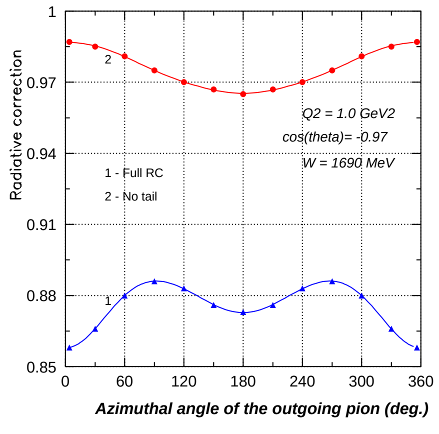

Figure 3: Radiative corrections evaluated at W= 1690 MeV as a function of ϕ (1) by including all radiative processes, and (2) by leaving out contribution of the radiative tail.

The discussed features of the radiative corrections, which have become available due to EXCLUDAD code, can not be confronted with the results of the approach [2] which are hidden in Monte Carlo simulation. This is an evident disadvantage of the currently used

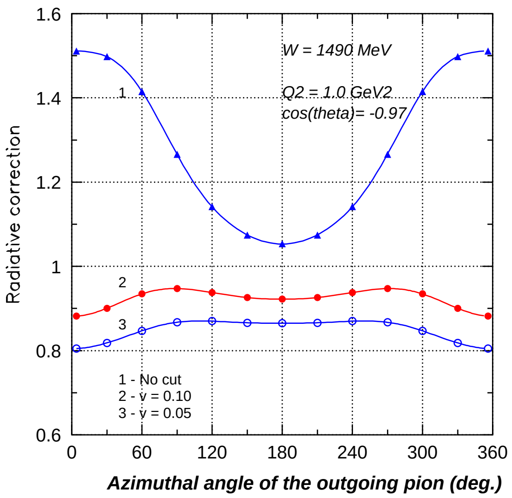

Figure 4: Radiative corrections evaluated at W= 1490 MeV as a function of ϕ by including all radiative processes - (1). The effect of inelasticity cuts $v = 0.10$ GeV^2 and $v = 0.05$ GeV^2 is shown with lines (2) and (3), respectively.

procedure of the radiative corrections. On the other hand, the latter is more practical for the simulation of the detector acceptance since it offers a possibility to directly generate the radiative tail caused by the internal real photon radiation.

The possible strategy of the application of the procedure of the radiative corrections for the data analysis is as follows:

- Upgrading EXCLURAD code in a way similar to the splitting δ_R in two parts, δ_{R1}, which is evaluated analytically and is virtually constant, and $\delta_{R2}(x_r)$, as it is realized in ref. [2];
- Generating several Monte Carlo samples at certain kinematics by switching off effects of photon radiation in order to conduct a comparison with the features of the corrections found from EXCLURAD.

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