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RADIATIVE CORRECTIONS FOR (e,elp) COINCIDENCE EXPERIMENTS

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Résumé : Dans cet article, nous présentons une formule de queue radiative pour l'analyse des expériences (e, e'N) en coïncidence. On calcule d'abord en première approximation de Born la section efficace différentielle en énergie et angle pour toutes les particules finales pour le rayonnement de freinage associé avec l'émission d'un nucléon. Cette formule est ensuite intégrée sur tous les angles du photon dans l'approximation de pic.

Abstract : In this paper, a formula for the radiative tail, suitable for use in the analyses of (ee'N) coincidence experiments is derived. We first calculate the cross section differential in the energies and angles of all final particles for bremsstrahlung associated with the emission of a nucleon, in first Born approximation. This cross section is then integrated over the angles of the unobserved photon, using the peaking approximation, to give an expression for the radiative tail in nucleon emission processes.

As in all electron scattering processes, the radiative corrections are expected to be important when a nucleon is detected in coincidence with the final electron. It is true that one thus avoids the considerable difficulties with background that arise from the large radiative tail from the elastic peak. However, the inelastic radiative tail of the continuum levels can still contribute, and the usual radiative correction for inelastic scattering[1] arising from the emission and absorption of virtual photons, and the emission of real soft photons, must still be applied. This correction is given to lowest order by

$$d\sigma^- = d\sigma_0 (1 - \delta)$$  \hspace{1cm} (1)

where $d\sigma_0$ is the uncorrected cross section and

$$\delta = \frac{\alpha}{\pi} \left\{ \left( e \frac{E_{12}}{E_1} - \frac{E_{12}}{E_2} \right) \left( e \frac{q^2}{m^2} - 1 \right) + \frac{13}{16} \right. $$

$$+ \frac{1}{4} \left( \frac{1}{E_1} + \frac{1}{E_2} \right) \left( \frac{1}{E_1} - \frac{1}{E_2} \right) \left( \cos^2 \frac{\theta}{2} - \frac{1}{4} \right) \right\}$$  \hspace{1cm} (2)

This correction depends only on the electron kinematics, and is independent of what happens in the target. Thus it is exactly the same as the correction for inelastic scattering without detection of a nucleon.

In addition, corrections due to emission of a hard photon of energy $k$, in addition to the proton, as shown in Fig. 1, must be considered. We consider only bremsstrahlung from the electron. This process is expected to dominate, since the electron mass is so much smaller than the other masses involved. We concentrate only on photon emission in the field of the target nucleus. Radiative losses corresponding to straggling in the target ($\chi^2$ effects) will not be discussed here. But since they do not depend on the specific nuclear process being studied, but only on the electron kinematics, it is expected that these effects can be treated exactly as they are when only the electron is detected. To obtain a formula useful for the analyses of (e, e'N) coincidence experiments, it is necessary to calculate the cross section differential in the energy and angles of the unobserved photon. This last is done by using the peaking approximation. The

Fig. 1 Diagrams for bremsstrahlung accompanying nucleon emission
details will appear in Nuclear Physics [2] and will therefore not be given here. The final result is:

\[
\frac{d^2\sigma}{d\Omega dE_d dE_p d^2k} \propto \frac{\alpha}{\pi k} \frac{e^{\chi_k}}{e^{\chi_k}} \ln \frac{Z}{m} \frac{d^2\sigma}{d\Omega dE_d dE_p d^2k} \left(\frac{E_1 - k}{E_1 + k}\right) + \frac{d^2\sigma}{d\Omega dE_d dE_p d^2k} \left(\frac{E_1 + k}{E_1 - k}\right)
\]

where

\[
\check{q}^L = \omega^L + 4 \epsilon_1 (E_1 + k) \sin^2 \frac{k}{E_1 + k} \theta
\]

\[
\check{q}^L = \omega^L + q \epsilon_1 (E_1 - k) \sin^2 \frac{k}{E_1 - k} \theta
\]

\[
\omega = E_1 - E_2 - k
\]

and

\[
\frac{d^2\sigma}{d\Omega dE_d dE_p d^2k} \propto \frac{\omega^L}{E_1 + k} \frac{E_p}{E_1} \cos^2 \frac{k}{E_1} \sin \frac{k}{E_1} \theta \times \left[\left(\frac{q^L - \omega^L}{q^L}\right)^2 W_C + \left(\frac{q^L - \omega^L}{q^L} + \tan \frac{k}{E_1} \theta\right) W_T + \left(\frac{q^L - \omega^L}{q^L} \cos^2 \frac{k}{E_1} \theta + \tan \frac{k}{E_1} \theta\right) W_S\right]
\]

is the (e, e'N) coincidence cross section without radiative corrections as given by de Forest. [3] The form factors \(W_C, W_T, W_I\) and \(W_S\) are discussed in Ref. 3. Observe that this formula is very similar to the peaking terms in the expression for the radiative tail for inelastic scattering as given by Maximon and Isabelle. [4] Thus, to the extent that the peaking approximation is valid, the radiative corrections to \(e, e'p\) can be handled just as they are for the case of ordinary \(e, e'p\) experiments.

The cross section \(d\sigma/dQ\left(e_1, k, E_1, q, \Omega, \Theta_1\right)\) appears in the formula for the radiative tail. This means that one must know this cross section for all values of the incident energy between threshold for proton emission and \(E_1\) (this is of course an improvement over needing to know it for all values less than \(E_1\)). Since our theoretical knowledge of the \(e, e'p\) process is still somewhat crude, it will be necessary to perform an unfolding of the spectra, using experimental data taken at lower incident energies.

In order to give an idea of the effect of the radiative corrections, missing energy spectra for kinematics similar to those of the Saclay experiment [5]

\[
(E_1 = 700 MeV, 1.3, t = 0, E_p = 87 MeV) \Theta_1 \text{ varied with } E_2
\]

so as to keep \(P_2 - 2\) fixed and \(\varphi, \vartheta\) (coplanar experiment) using the quasielastic model for the nucleon emission process, and a very simple single particle harmonic oscillator shell model (but with phenomenological shell binding energies taken from experiment) to describe the nuclear structure, were computed. The results are shown in Figs. 2, 3. In each figure the dashed curve is computed directly from the formulas given in Ref. 3, and the solid curve is obtained by multiplying the computed cross section by \(4 - \delta\), then adding the integral of \(E\) over \(k\) from \(\Delta E\) to \(E_1 - E_2 - E_p\).

Even though the model used is somewhat crude, certain qualitative features exhibited by the curves are probably reproduced in the exact cross sections. Peaks are reduced in height, by about 30 %, for emission of a valence shell proton, and the cross section is increased by a factor 3-4 at large missing energy. Peaks corresponding to emission of an inner shell nucleon tend to be washed out (due to a filling in of the "valley" between the peaks) but can still be observed as shoulders if the shell is sufficiently narrow.

REFERENCES

[2] Borie (E.) and Drechsel (D.), to be published in Nuclear Physics.
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Fig. 2  Missing energy spectrum for $^{12}$C in arbitrary units

Fig. 3  Missing energy spectrum for $^{40}$Ca in arbitrary units