CHAPTER IV

Empirical Determination $I_0/C$ and $\Sigma$ with Unpolarized
Photons at Near-threshold Energy Region


Presented at the Symposium on 'Particles and Fields' held at the Univ. of Madras, 30 Dec.
'70 - 4 Jan. '71.
We find that the measurements of the asymmetry ratio \( \Sigma (90^\circ) \) and the quantity like \( I_0/C \) has been made at as low as 230 MeV energy where linearly polarized photons are already available. Below this energy we do not have experimental information about these quantities. However, there is a critical cancellation of several multipole contributions in \( I_0 \) and \( C \) near threshold, with a zero in \( I_0 \) and possibly also in \( C \); thus the empirical knowledge of the quantity \( I_0/C \) would be certainly interesting in this energy range. Also in the case of asymmetry ratio \( \Sigma (90^\circ) \) one finds that at very low energy the discrepancy between the experiment and the theory is quite large, necessitating further experimental information of this quantity below 230 MeV.

We suggest to use the elastic differential cross-sections data for \( \bar{\pi}^0 \) meson photoproduction on spin zero nuclei to determine \( I_0/C \) and \( \Sigma \) below 230 MeV without the use of the linearly polarized photons.

From eqns. (A.2) and (A.3) (Appendix A) we see that for plane polarized photons:

1. Perpendicular to the production plane:

\[
(4.1) \quad L L_I = |z| \sin^2 \theta
\]
\[
(4.2) \quad \vec{K} \cdot \vec{K}_L^* = |F_1|^2 + |F_2|^2 \cos^2 \theta - 2 \text{Re} (F_1^* F_2) \cos \theta
\]

(ii) Parallel to the production plane

\[
(4.3) \quad L \cdot L_{II}^* = 0
\]

\[
(4.4) \quad \vec{K} \cdot \vec{K}_{II}^* = |F_1|^2 + |F_2|^2 - 2 \text{Re} (F_1^* F_2) \cos \theta + 2 \text{Re} (F_2^* F_3) + 2 \text{Re} (F_1^* F_4) + 2 \text{Re} (F_3^* F_4) \cos \theta
\]

If we rewrite the above expressions in terms of the multipole amplitudes we get from eqn. (3.13):

\[
(4.5) \quad I_0 = \frac{1}{2} \left( \vec{K} \cdot \vec{K}_{II}^* - \vec{K} \cdot \vec{K}_L^* - L \cdot L_{II}^* \right)_{\theta = 90^\circ}
\]

and

\[
(4.6) \quad (\vec{K} \cdot \vec{K}_{II}^* - \vec{K} \cdot \vec{K}_L^*)_{\theta = 90^\circ} = \left| (3F_{1+} - M_{1+} + M_{1-}) \right|^2
\]

Using eqn. (4.6) in eqn. (4.5) we obtain

\[
(4.7) \quad I_0 = \frac{1}{2} \left[ (3F_{1+} - M_{1+} + M_{1-}) \right]^2 - \frac{1}{2} \sum \frac{L \cdot L_{II}^* (90^\circ)}{4}
\]

Making use of eqns. (3.20) and (3.28) we have

\[
(4.8) \quad I_0 = \frac{n}{2} - \frac{v}{2} \left( \frac{d\sigma}{d\Omega} \right)_A (90^\circ) \times \text{(form factor term)}^{-1}
\]

where

\[
(4.9) \quad \chi = \left[ \frac{2v}{2} \frac{d\sigma}{d\Omega} (90^\circ) - \frac{2v}{2} \left( \frac{d\sigma}{d\Omega} \right)_A (\text{form factor term})^{-1} \right]^{1/2} - \frac{\nu}{2} \left[ \sqrt{\frac{d\sigma}{d\Omega} (0^\circ)} + \sqrt{\frac{d\sigma}{d\Omega} (180^\circ)} \right]^{1/2}
\]
Further the asymmetry ratio is given by

\[
\Sigma = \frac{\left( \frac{d\sigma}{d\omega} \right)_\perp - \left( \frac{d\sigma}{d\omega} \right)_\parallel}{\left( \frac{d\sigma}{d\omega} \right)_\perp + \left( \frac{d\sigma}{d\omega} \right)_\parallel}
\]

(4.10)

and since

\[
\left( \frac{d\sigma}{d\omega} \right)_\parallel = \frac{q^2}{\omega} \left( \vec{K} \cdot \vec{K}_\parallel^* \right)
\]

(4.11)

\[
\left( \frac{d\sigma}{d\omega} \right)_\perp = \frac{q^2}{\omega} \left( \vec{L}_\perp \cdot \vec{k}_\perp + \vec{k}_\perp \cdot \vec{L}_\perp^* \right)
\]

(4.12)

where \(\left( \frac{d\sigma}{d\omega} \right)_\parallel, \parallel\) are the \(\pi^0\) photoproduction cross-sections for photons linearly polarized perpendicular or parallel to the production plane, we get

\[
\Sigma = \frac{\frac{q^2}{\omega} \left( \vec{L}_\perp \cdot \vec{k}_\perp + \vec{k}_\perp \cdot \vec{L}_\perp^* \right)}{\frac{q^2}{\omega} \left( \vec{L}_\perp \cdot \vec{k}_\perp + \vec{k}_\perp \cdot \vec{L}_\perp^* \right)}
\]

(4.13)

Using eqn. (4.5) we get
Since $\theta$ is determined from the differential cross-sections for $\pi^0$ photoproduction on nucleon with unpolarized photons using the expression (3.8), we suggest to determine the important quantities like $I_0$, $I_0/C$ and $\Sigma(90^\circ)$ below $\approx 230$ MeV (the importance of these quantities have been discussed in ref.(1) while the differential cross-sections for $\pi^0$ meson photoproduction on spin zero nuclei are there. It is interesting to note here that all the necessary experimental data are available at present.