Inelastic π^0 Photo Production in Primex

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Abstract

It is shown that the inelastic contribution in the Primex experiment must be handled differently then it was in the Cornell experiment. It is suggested that we extract the experimental values of double differential cross section $d^2\sigma/d\Omega dE_{\pi 0}(\theta_{\pi^0}, E_{\pi^0})$ of the background in the inelastic region.

The Cornell measurement was performed with a bremsstrahlung beam with very crude energy resolution[1]. Due to this they wrote the observed cross section as

$$\frac{d\sigma}{d\Omega} = \mathrm{b_p} \cdot \frac{d\sigma_\mathrm{P}}{d\Omega} + \mathrm{b_{nc}} \cdot \frac{d\sigma_\mathrm{NC}}{d\Omega} + cos\phi \cdot 2\sqrt{\mathrm{b_p b_{nc}} \frac{d\sigma_\mathrm{P}}{d\Omega} \frac{d\sigma_\mathrm{NC}}{d\Omega}} + \mathrm{b_b} \cdot \frac{d\sigma_\mathrm{Inc}}{d\Omega}, \quad (1)$$

where the contributions are: P for Primakoff; NC for nuclear coherent, the Primakoff-nuclear coherent interference proportional to $cos(\phi)$; and inc for the incoherent cross sections (see [2] for details). Up to the present time all of the Primex analysis groups have been using the same equation. The main purpose of this report is to show that the incoherent cross section term should not be used in the analysis that we are carrying out for the Primex experiment. The reason is that we have excellent energy resolution due to the fact that we have tagged photons and a high resolution detector. For that reason the Primex analysis utilizes the fraction $x = E_{\pi^0}/k$, the measured π^0 energy relative to the tagger energy k. By extrapolating the clearly inelastic background into the region of $x \simeq 1$, the inelastic(incoherent) background has been estimated and subtracted. To the extent that this has been properly done we should not have any inelastic(incoherent) contribution in Eq.2. Therefore to include it would be double counting. It is therefore suggested that in the future we use only the first three terms

$$\frac{d\sigma}{d\Omega} = \mathrm{b_p} \cdot \frac{d\sigma_{\mathrm{P}}}{d\Omega} + \mathrm{b_{nc}} \cdot \frac{d\sigma_{\mathrm{NC}}}{d\Omega} + cos\phi \cdot 2\sqrt{\mathrm{b_p b_{nc}} \frac{d\sigma_{\mathrm{P}}}{d\Omega} \frac{d\sigma_{\mathrm{NC}}}{d\Omega}}, \tag{2}$$

The second suggestion is that we should extract from this experiment the inelastic double differential cross section $d^2\sigma/d\Omega dE_{\pi 0}(\theta_{\pi^0}, E_{\pi^0})$. This, unexpectedly large, background is in fact a measurement that, as far as I know, has never been previously made on complex nuclei. To be sure it is a complicated process. There are several different effects at play here. First is heavy meson production (heavier then the pion) which then decay into the π^0 mesons that we detect. There is some data for this at JLab for nucleon targets. However there is no data for nuclei that I am aware of. The largest production cross sections are likely to be for quasi-free photo-production. The produced heavy mesons will then sometimes decay in forward π^0 mesons which we can detect. Both the heavy mesons and the produced π^0 mesons can interact with the nucleus in the final state. Some of these interactions will change the fluxes of these mesons and can also result in further energy loss. The second π^0 production mechanism involves pion photo-production in the nucleus. The larger processes include coherent π^0 production and quasi-free pion production. The latter case involves all four charge channel reactions

$$\begin{aligned} \gamma + p &\to \pi^0 + p \\ \gamma + n &\to \pi^0 + n \\ \gamma + p &\to \pi^+ + n \\ \gamma + n &\to \pi^- + p \end{aligned} \tag{3}$$

The largest quasi-free cross sections will occur with the pions having less then the beam energy. In addition there is the possibility of energy loss in the final state. Note also that pion charge exchange is possible so that the charged pions can lead to π^0 production in the final state. At the same time there are many mechanisms that lead to reduced pion flux in the final state.

The entire inelastic cross section is therefore rather complicated. Nevertheless there are calculations[3] that do this and our data can be used to challenge them. I am looking forward to the next collaboration meeting when we shall meet with Tulio Rodrigues and hear about his calculations of $d^2\sigma/d\Omega dE_{\pi 0}(\theta_{\pi^0}, E_{\pi^0})$.

References

[1] A.Browman et al., Phys. Rev. Lett. 33, 400(1974).

[2] D. McNulty and A.M. Bernstein, π^0 Lifetime Extraction: Methods and Result, Primex Report, Dec. 2006.

[3] T. E. Rodrigues et al., Phys. Rev. C71, 051603(2005).