Brief Reports

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Observation of two-photon emission after pion capture in ^{12}C and ^{9}Be

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In this note we report our final results for the $(\pi^-, \gamma\gamma)$ capture mode in ^{12}C and ^{9}Be and comment on the discrepancy observed between theory and two experiments at large interphoton angles.

The description of the experimental setup used in the measurement of photon pair emission after π^- capture in carbon and beryllium and other details concerning auxiliary measurements and tests are contained in Refs. 1, 2, and 3. Since the publication of our first preliminary results,[1] further data analysis has shown that more stringent energy cuts applied on the incoming pion energy-loss distribution, which selects the pions of energy below the charge-exchange threshold, would modify slightly the observed angular distribution for photons at great interphoton angles ($\theta_{\gamma\gamma} > 120°$), especially for the carbon target.

Such a distribution is shown in Fig. 1, together with the results from the University of the British Columbia group,[4] and constitute our final results. We have verified that still more severe cuts do not change this result: the contribution of a substantial background from in-flight reaction mechanisms can therefore be excluded.

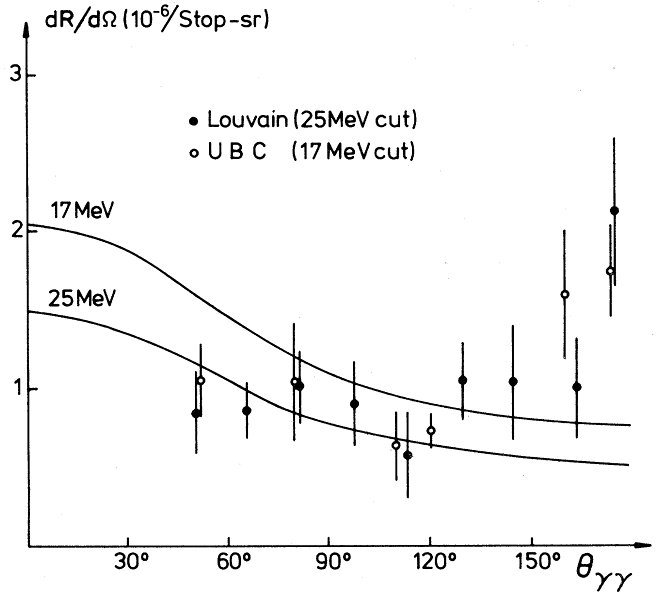

FIG. 1. Angular distribution of the photons in the $^{12}C(\pi^-, \gamma\gamma)X$ reaction; full lines are the theoretical predictions of Ref. 5. Energy resolution is included in the theoretical result for 25 MeV photon threshold.

The measured branching ratios $(\pi^- \rightarrow \gamma\gamma)/(\pi^- \rightarrow \text{all})$ are $(1.1 \pm 0.2)10^{-5}$ for C $[(1.2 \pm 0.2)10^{-5}$; Ref. 4] and $(1.1 \pm 0.1)10^{-5}$ for Be. The errors indicated here, include the contribution of our uncertainty on the acceptance of the detector. In the comparison of our results with the ones obtained by the UBC group, one has to keep in mind the energy resolution of the respective instruments and the fact that our photon energy threshold is 25 MeV per photon, compared to 17 MeV in Ref. 4. Taking into account these differences, the agreement between the two results is excellent.

Our results revealed also that the residual excitation of the daughter nucleus is rather similar to the one observed in ordinary radiative capture.

The $\gamma\gamma$ angular correlation calculated for ^{12}C by Christillin and Ericson[5] in a "conventional" model, disregarding any possible anomaly in the nuclear pion field, is also presented in Fig. 1 for the two thresholds used in the experiments. The full line for the 25 MeV threshold takes into account the energy resolution of our lead-glass detectors.

The excess observed, between calculation and experiments, at $\theta_{\gamma\gamma} > 120°$ could possibly be assigned to a slight contamination of the targets with hydrogeneous compounds or with absorbed gases of low charge-exchange threshold, leading to pion charge exchange followed by π^0 decay.

However, (i) the well-known angular distribution of the π^0-decay photons does not agree with the observed distribution; (ii) a very similar anomaly (excess of photons with $\theta_{\gamma\gamma} \cong 180°$) can be observed both in our results obtained with a beryllium target (Fig. 2) and also in the data of the UBC group for carbon: a fortuitous equality of background for the three targets seems improbable.

Other possible explanations for the excess of back-to-back photons might be (i) a contribution of mechanisms (mesonic effects) not considered in Ref. 5 such as $\pi^- - $"$\pi^+$" an-

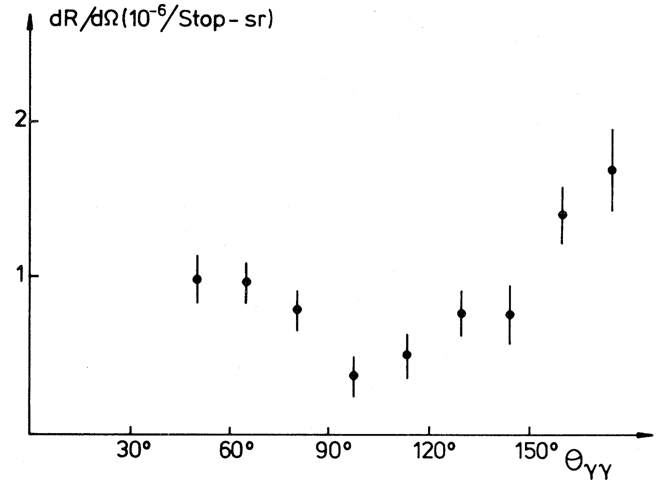

FIG. 2. Angular distribution for the photons in the $^{9}Be(\pi^-, \gamma\gamma)X$ reaction.

nihilation; the goal of the authors was in fact "to establish a good theoretical comparison standard, which can serve to pinpoint major experimental discrepancies due to mesonic effects"; (ii) a new mechanism, like the decay of a virtual π^0 near the mass shell,[6] which should be added to the previous estimation. A comparison of our result with the prediction of Ref. 5 gives an upper limit for the yield of such a process: $R(``\pi^{0}") \lesssim (1.4 \pm 0.5) 10^{-6}$ per stopped pion.

For comparison, we observe that the early estimate of Ericson and Wilkin[6] is in the range 10^{-6}–10^{-7}; further theoretical investigations would be needed to provide a more accurate evaluation both for yield and interphoton angular distribution from this mechanism.

Further experiments with improved energy and angular resolution around $\theta_{\gamma\gamma} \sim 180°$ would held to clarify this issue. This information could be important in our understanding of virtual pion field in nuclear matter.

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