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# Angular Correlation of Scattered Annihilation Photons, to Test the Possibility of Hidden Variables in Quantum Theory*

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**Abstract.** Angular correlations of the annihilation photons, Compton scattered by plastic scintillators and detected by means of NaI (Tl) crystals, have been measured in order to test the possibility of deviations of the experimental results from the predictions of the quantum theory.
In fact, Jauch and Bohm, starting with different motivations, both arrive at the possibility of a lower correlation ratio between the two orthogonal polarization states of the two photons than predicted by quantum theory.
This in turn should give a lower azimuthal anisotropy in the angular correlations.
Our experimental results compared with the theoretical predictions, after correction for finite geometry by means of a Montecarlo method, do not confirm quantum theory and exclude the hypotheses of Jauch and of Bohm.
We are continuing the experiment in order to test wether the breakdown in the polarization correlation depends on the distance (spatial and/or temporal) between the two correlated scattering events, as suggested by Jauch.

**Index Heading:** Positron annihilation

Recently a new characterization of the notion of state for an individual system in quantum mechanics has been advanced, in order to eliminate several difficulties of the theory mainly connected with two interacting systems as, for instance, in the formal analysis of the measuring process.
This new notion of quantum state maintains essentially that only mixtures obtained from a statistical ensemble in which every individual is in a pure state can be admitted in the theory [1].
As a consequence of the previous postulate definite predictions can be obtained in the case of the two-photons dissintegration of positronium.
Such predictions are identical with those obtained some time ago by other authors [2], although starting with different motivations, and differ from the predictions derived from the standard interpretation of quantum mechanics [3].
In order to discriminate between the two previsions we set up an experiment which is schematically shown in Fig. 1.
A $^{22}$Na positron source S is annihilating in a plexiglass container.
Because of the experimental set-up the triplet state can be neglected and we may assume that all the decays come from the singlet state and, according to the theory, the two photons will emerge in opposite states of circular polarization, which we analyse by means of Compton scatterers, $S_1$ and $S_2$.

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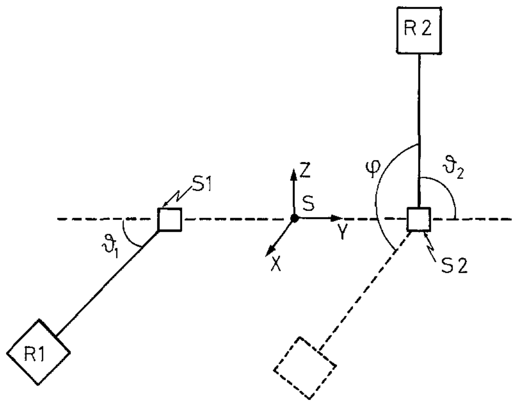


Fig. 1. Sketch of the experimental apparatus

These scatterers are made out of plastic scintillators (NE 202) and we measure quadruple coincidences between the scatterers and the two NaI(Tl) detectors, $R_1$ and $R_2$, in order to improve the signal to noise ratio ($\approx 30$) and the coincidence resolving time ($\approx 30$ ns).

The scattering angles, $\theta_1$ and $\theta_2$, and the azimuthal angle, $\Phi$, between the two scattering planes can be varied.

In Fig. 2 the ratio

$$N(\theta, \theta, 90°)/N(\theta, \theta, 0°)$$

between the coincidence counting rate $N(\theta, \theta, \Phi)$ measured for orthogonal scattering planes has been reported as a function of the scattering angle ($\theta_1 = \theta_2 = \theta$). The upper curve represents the predictions of the standard quantum theory [3], while the lower curve indicates the predictions of the newly proposed theory [1, 2]. Both theoretical curves have been corrected for finite geometry, absorbtion in the scatterers and in the detectors, and for instrumental thresholds by Montecarlo calculations.

Our experimental points are intermediate between the two theories.

The same situation can be seen in Fig. 3 where we have reported another series of measurements. In this case the ratio

$$N(60°, 60°, \Phi)/N(60°, 60°, 0°)$$

has been recorded as function of the azimuthal angle. The meaning of the theoretical curve is, also in this case, as given above.

Because the present results do not agree with either of the two theories we are continuing the experiment in order to test the advanced hypothesis [1] that the

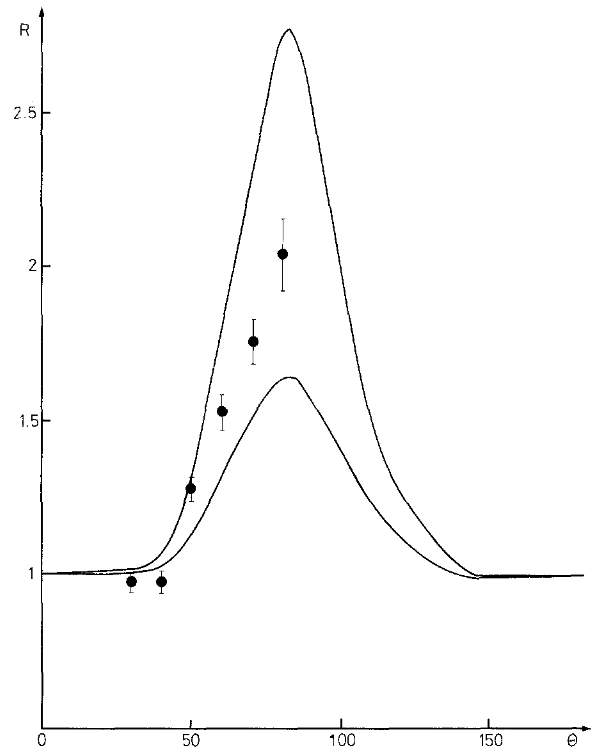


Fig. 2. Anisotropy ratio versus the scattering angle. (Upper curve: theoretical prevision corrected for finite geometry for the standard quantum theory. Lower curve: idem, for the newly proposed theory [1, 2] – ●: present results)

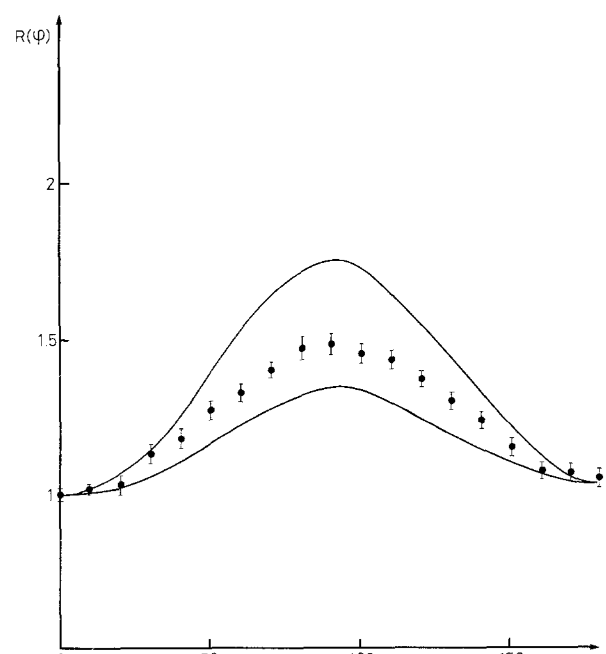


Fig. 3. Anisotropy ratio versus the azimuthal angle. (Legend as in Fig. 2)

state of polarization of the two correlated photons may depend on the distance of the two scatterers (10 cm in our case). This hypothesis implies that for distances much less than the coherence length of the photons ($\approx 7$ cm in our case) one should obtain agreement with the upper curve, while for larger distances the lower curve should be appropriate. Some preliminary results obtained by us seem to confirm such hypothesis; however the statistics, for this result, is not so good to be definite about this point.

We are going to improve the geometry of our experimental apparatus in order to get a better statistics with reasonable measuring periods also at those larger distances.

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