DEUTERON ELECTRIC QUADRUPOLE MOMENT*

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The nuclear radio-frequency spectra of molecular hydrogen and deuterium, first observed by Rabi et al.,[1] were reinvestigated by Ramsey et al.[2] From these experiments the value of the quadrupole coupling constant eQq, in the $v=0$, $J=1$ vibrational-rotational level of the electronic ground state of D_2, was determined with an estimated accuracy of better than 1 part in 10^3.

An accurate value for the deuteron electric quadrupole moment Q can be derived from this result if q, the electric field gradient along the molecular axis at one deuteron, is evaluated theoretically. This was done by Nordsieck[3] and later by Newell[4] using a trial molecular wave function which gave a molecular binding energy D_e of 4.566 ev.[5]

The present author has calculated q from a trial function which gives $D_e=4.728$ ev. This is much closer to the experimental value[6] of 4.747 ev. The trial function was constructed in the framework of the Born-Oppenheimer approximation. Its electronic part consisted of an expansion in the electronic coordinates and the interelectronic distance, of the type first investigated by James and Coolidge,[7] and recently by Kolos and Roothaan.[8]

The value of q obtained from this function yields $Q=2.82\times10^{-27}$ cm^2. This is about 3% larger than the currently accepted value based on Newell's result.

The discrepancy is larger than the estimate given by Newell.[4] Newell, however, obtained this estimate by an admittedly crude procedure. In addition it should be noted that q, in these calculations, is not stationary. Consequently no rigorous estimate of the error in q can actually be made.

The details of this calculation will be given in a forthcoming publication.

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POSSIBLE EXISTENCE OF A NEW K' MESON*

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It has been experimentally established that the Λ particles produced in the reaction

$$p+\pi^- \rightarrow K^0+\Lambda \qquad (1)$$

are strongly peaked backward in the c.m. system. Pais[1] has tried to explain this result by assuming the existence of a $KK\pi$ interaction and that the main contribution to reaction (1) comes from the Feynman graph of Fig. 1, assuming χ^+ to be a K^+ meson. He has obtained a reasonable qualitative agreement with the available experimental data at 1.1 Bev. However, his scheme, supposing opposite parities for K^+ and K^0, leads to many problems of difficult solution, arising from the failure of charge independence of the π interaction. One such difficulty results from the lack of a $KK\pi^0$ interaction, which gives rise to a mass of charged π's smaller than that of π^0.[2]

In the present paper we shall try, maintaining the convenient features of the Pais scheme, to

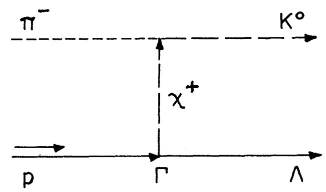

FIG. 1. Feynman diagram of the assumed predominant contribution to $K^0\Lambda$ production.

overcome such difficulties by assuming the existence of another K' meson of the same hypercharge and isospin (1/2) as those of the ordinary K meson but of opposite parity.[3]

Reaction (1) proceeds now mainly via the same graph as in Fig. 1 but with the intermediate χ^+ being a K'^+ meson instead of K^+.

In order to compute the differential cross sections of reaction (1) we add to the usual d'Espagnat Prentki interaction Hamiltonian density a $KK'\pi$ and a $\Lambda K'N$ term:

$$2m_K f(\bar{K}\vec{\tau}K' + \bar{K}'\vec{\tau}K)\cdot\vec{\pi} + g(\bar{K}'\bar{\Lambda}\Gamma N + \text{H.c.}), \qquad (2)$$

where m_K is the mass of the K meson and Γ is 1 or γ_5 according to the parity of K'.

Using the Born approximation, we get for the differential cross section:

$$d\sigma/d\Omega = A\,\frac{1 + v_p v_\Lambda \cos\theta \pm m_\Lambda m_p/E_\Lambda E_p}{[m_\pi^2 + m_K^2 - \mu^2 - 2E_\pi E_K(1 + v_\pi v_K \cos\theta)]^2}, \qquad (3a)$$

$$A = 4m_K^2(f^2/4\pi)(g^2/4\pi)p_K E_p E_\Lambda/(E_p + E_\pi)^2 p_\pi, \qquad (3b)$$

where μ is the mass of the K' meson and θ is the angle between π and Λ in the c.m. system. The plus sign corresponds to $\Gamma = 1$ (K' scalar), and the minus to $\Gamma = \gamma_5$ (K' pseudoscalar).

Although the use of the Born approximation is not well justified, we compared (3) with the available experimental distributions at several values of the energy with the best statistics.[4,5] In this way we determined in each case the value of μ which gave the best fit. These values of μ (or μ^2) are given in Table I, for both scalar and pseudoscalar K'. The values of $fg/4\pi$ are also indicated for the cases where total cross sections were available. The most probable value was found to be

$$\mu = 605 \pm 49 \text{ Mev} \quad (K' \text{ scalar}), \qquad (4a)$$

$$\mu = 176 \pm 46 \text{ Mev} \quad (K' \text{ pseudoscalar}). \qquad (4b)$$

The last possibility can be immediately excluded since it would lead to a fast decay of K into $K' + \pi$. Thus we conclude that the K' (if it exists) is scalar, K being pseudoscalar in agreement with other experimental indications.[6]

In Fig. 2 all experimental data are plotted together to give an idea of the goodness of fit with a unique mass in the case of scalar K'. In order to do this we introduce the notation (c.m. system):

$$x(\theta, E) = 2E_\pi E_K(1 + v_\pi v_K \cos\theta) - (m_\pi^2 + m_K^2), \qquad (5a)$$

$$z^{-2}(\theta, E) = \frac{d\sigma/d\Omega}{\sigma(E)L(\theta, E)} \int \frac{L(\theta, E)d\Omega}{[\mu^2 + x(\theta, E)]^2}, \qquad (5b)$$

$$L(\theta, E) = 1 + v_p v_\Lambda \cos\theta + m_\Lambda m_p/E_\Lambda E_p. \qquad (5c)$$

Thus Eqs. (3) imply that

$$z(\theta, E) = \mu^2 + x(\theta, E), \qquad (6)$$

for all energies ($E = E_\pi^{\text{lab}}$) and angles.

The x and z coordinates for each experimental point plotted were obtained from (5) using $\mu = 605$ Mev. The values of $(1/\sigma)d\sigma/d\Omega$ and $\cos\theta$ used were average values in the intervals in which the angular distribution histograms, represented as functions of $\cos\theta$, were divided. The straight

Table I. Values of the mass of the hypothetical K' meson and the product of the coupling constants obtained by fitting the experimental data to the theoretical curve.

T_π^{lab} [a] (Bev)	K' scalar μ (Bev)	K' scalar $fg/4\pi$	K' pseudoscalar μ^2 (Bev^2)	K' pseudoscalar $fg/4\pi$
0.902[b]	0.90 ± 0.20	...	0.048 ± 0.034	...
0.907[b]	0.66 ± 0.12	...	0.063 ± 0.035	...
0.910[c]	0.45 ± 0.11	0.33 ± 0.07	−0.012 ± 0.029	0.70 ± 0.10
0.960[c]	0.49 ± 0.11	0.43 ± 0.09	0.011 ± 0.099	0.91 ± 0.40
1.200[c]	0.59 ± 0.11	0.31 ± 0.06	0.034 ± 0.039	0.55 ± 0.08
1.300[c]	0.80 ± 0.12	0.48 ± 0.09	0.103 ± 0.085	0.69 ± 0.08

[a] T_π^{lab} is the kinetic energy of the pion in the lab system.
[b] See reference 4.
[c] See reference 5.

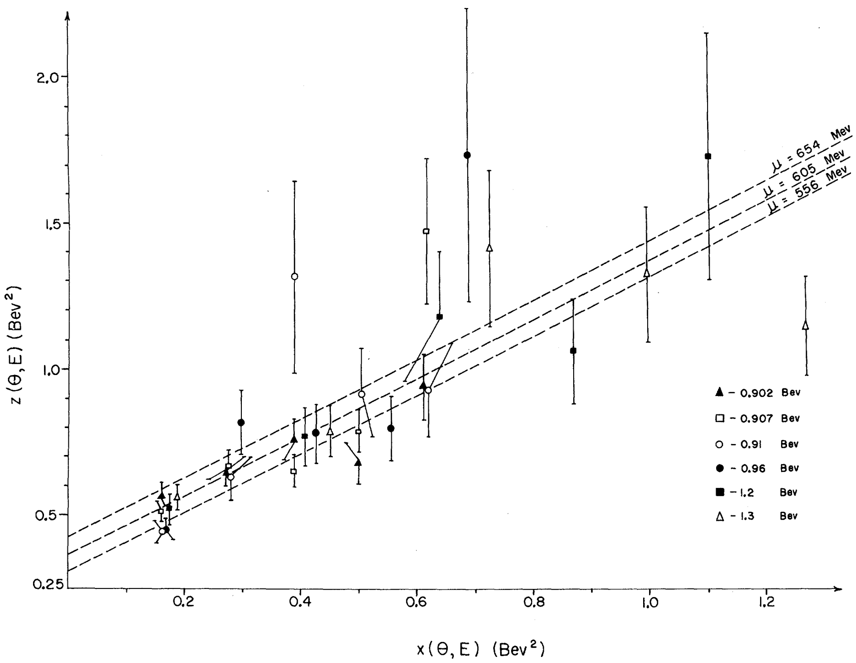

FIG. 2. Comparison of the experimental data on the angular distribution of Λ at several energies with theoretical curves (dashed lines). The values of the mass of the hypothetical K' meson are indicated. The coordinates x and z are defined by Eqs. (6).

lines indicated correspond to Eq. (6) for values of $\mu = 605$, and 605 ± 49 Mev. The fit of the experimental points in Fig. 2 with these theoretical lines seems to be very good except for the points to the right which correspond to $\cos\theta \sim 1$, as should be expected. These points also have poorer statistics. The fit in the case of pseudoscalar K' was not so good.

Actually the experimental points plotted are only appropriate for the comparison with the theoretical line for $\mu = 605$ Mev since z_{exp} depends on μ. However, for the two other values (605 ± 49 Mev) the experimental points would be only slightly shifted. If we interpret these results as indicating the existence of the K' meson, this meson should have a mass $\mu \geq m_K + m_\pi$ for otherwise it would have been already observed. Then K' should be very short-lived since the interaction leading to $K' \to K + \pi$ is strong. However, it cannot be excluded that the K' meson does not exist, representing only a pair of π and K, which are exchanged between the baryons and a $KK\pi\pi$ vertex. The existence of the K' can be tested indirectly by the study of the reaction

$$\pi + N \to K + \pi + \Lambda \text{ (or } \Sigma\text{)}, \qquad (7)$$

if the graph of Fig. 3(a) gives a significant contribution. Thus there should be a characteristic peaking in the energy distribution of Λ (or Σ) in the c.m. system at a point depending on the mass of K'. The values (4a) should not, however, be taken very seriously due to the approximations made which are more satisfactory for higher π energies. As seen from Table I, larger values of μ are obtained at higher energies. Also in this peak the Λ (and Σ) should have some backward preference and strong $K\pi$ angular correlations should be observed. The most spectacular effects of similar kind would occur, however, in the reaction

$$K + N \to K + \pi + N, \qquad (8)$$

due to the graph of Fig. 3(b).

A more detailed version of the present paper will appear in Anais da Academia Brasileira de Ciências.

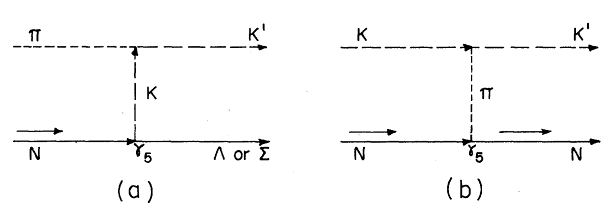

FIG. 3. Diagrams of (a) π production of K'; (b) scattering of K producing a K'.

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SOLAR-PRODUCED COSMIC RAYS NEAR THE NORTH AND SOUTH POLES*

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The sudden arrival of solar-produced cosmic radiation of sufficient energy to be detectable at ground stations, a relatively rare phenomenon, has for the first time been observed simultaneously by the two neutron monitors which are currently closest to the North and South geomagnetic poles. Two events, each of which appeared to be associated with a solar flare of Importance 3+, occurred on November 12 and 15, 1960, respectively, the former displaying some remarkable features.

The locations of the Arctic and Antarctic stations operated by the Bartol Research Foundation are listed in Table I, and the relevant data are plotted in Fig. 1. The intensity is expressed in terms of percent deviation from the preflare mean (0000 to 1200 U. T. on November 12) of barometric pressure-corrected counts, recorded during 15-minute intervals. It is apparent that, on November 12, the increase at both stations manifested an unusual double-hump structure, whereas the November 15 event is similar to previous flare-associated intensity enhancements.

It is interesting to note that, on November 12, greater increases in intensity were recorded at the Antarctic station during the period of the first hump. On the contrary, the increases at both stations were approximately equal thereafter, although there is some uncertainty in the comparison of the amplitudes of the second maximum on this date, owing to a 45-minute gap in the record during the weekly routine Ra-Be source runs.

As a quantitative measure of the relative intensity enhancement at the two polar stations, the ratios of the increases, ΔI(McMurdo)/ΔI(Thule), are also plotted in Fig. 1. The 12-hour preflare mean counting rate on each of the two respective dates is selected as reference level for the percent deviation, ΔI. This ratio attains a maximum about 30 minutes after onset, and approaches unity after approximately 5 hours on November 12. The first peak in the ratio ΔI(McMurdo)/ΔI(Thule) occurs during the rising portion of the first hump, while the second peak occurs between the two humps. A single peak of shorter duration also occurs during the rising portion of the event of November 15.

The onset times, and times and amplitudes of maxima, are listed in Table II. Onset is defined as the first 2-minute interval during which, together with five consecutive equal intervals, the

Table I. Locations of the polar neutron monitor stations.

Station	Geographic coordinates Latitude	Longitude	Altitude (meters)	Geomagnetic coordinates Latitude	Longitude
Thule	N 76.6°	W 68.8°	260	+88.0°	1.1°
McMurdo	S 77.9°	E 166.6°	48	−79.0°	294.3°