ence 10.) Collective effects are therefore absent in E2 transitions in which the isotopic spin changes, and one may assume that the shell model theory gives the correct values for the probabilities of these transitions. We note that the conclusion that the shell model theory cannot give the probabilities of quadrupole transitions is based on the analysis of transitions in which the isotopic spin does not change (see above).

The verification of the above assertion is of special interest in the region of light nuclei, where the isotopic spin may be considered a good quantum number and where, moreover, the shell model successfully explains the spectrum of energy levels. Within the p shell only a few pure E2 transitions with a change in the isotopic spin can be observed:

B^{10}	$3.58\ (2.0) \rightarrow 1.74\ (0.1)$,	C^{12}	$16.1\ (2.1) \rightarrow 0\ (0.0)$,
B^{10}	$4.77\ (2.0) \rightarrow 1.74\ (0.1)$,	N^{14}	$?\ (2.0) \rightarrow 2.31\ (0.1)$.
B^{10}	$6.02\ (4.2) \rightarrow 5.16\ (2.1)$,		

For the first three transitions experimental values are available only for the total Γ width of the level.[7,11] Γ, the width for the transition $16.1 \rightarrow 0$ in C^{12}, is equal to 0.72 ev (reference 12). In the limit of j-j coupling (the intermediate coupling parameter $\xi = \infty$) the ground state of C^{12} corresponds to the closed shell $p_{3/2}$, and the excited state at 16.1 Mev corresponds to the configuration $|p_{3/2}^{-1} p_{1/2}; 21\rangle$. Using the value $\langle r^2 \rangle = 5.7 \times 10^{-26}$ cm² (reference 6), we obtain, in this approximation, $\Gamma_{theor} = 0.87$ ev. Perturbation theoretical calculations show that Γ_{theor} decreases for deviations from strict j-j coupling, with $d\Gamma_{theor}/d(1/\xi) = 0.24$ ev in the limit of j-j coupling.

This example therefore confirms our previous contention that the increase in the probability of quadrupole transitions is connected with collective effects and that these effects vanish in transitions in which the isotopic spin changes. Unfortunately, experimental data are available only for the single case 16.1 (C^{12}).

In this connection the following experiments are of interest: (a) A measurement of τ for the transitions $3.58 \rightarrow 1.74$ Mev and $4.77 \rightarrow 1.74$ Mev in B^{10}. This can be done either by the Doppler method, e.g., in the reaction $C^{12}(d, \alpha)B^{10}$, or by measuring the relative transition probabilities from the states 3.58 and 4.77 Mev to the lower lying states. (b) A measurement of the relative probabilities in the mixed M1 + E2 transitions, in particular, in the transition $17.63 \rightarrow 2.9$ Mev in the nucleus Be^8, for which an experimental value for the total Γ width is available.[11]

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DIFFRACTION STRIPPING OF RELATIVISTIC PARTICLES

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In a number of papers[1-4] various authors have considered the diffraction dissociation of the deuteron on a "black" nucleus in the deuteron energy region $E_d \sim 100$ to 200 Mev. The nucleus is also black when $E_d \gtrsim 6$ Bev. We first show that the results obtained earlier[1-4] also apply for a relativistic deuteron.

First we consider diffraction scattering. If φ is the wave function for free motion the wave function for a deuteron which suffers diffraction at the nucleus is $\psi = \varphi\Omega(\rho_n)\Omega(\rho_p)$ (cf. reference 3). The subscripts n and p refer to the neutron and proton respectively, ρ is the radius vector of the particle in the plane perpendicular to the beam axis; $\Omega(\rho) = 0$ or 1 when $\rho \gtreqless R$, where R is the radius of the nucleus.

We find the expression for φ. Since the relative motion in the deuteron is nonrelativistic the wave function of the deuteron in the rest system is known. This wave function is

$$\xi_i \sqrt{\alpha/2\pi}\, e^{-iM\tau} e^{-\alpha r}/r,$$

where ξ_i denotes the spin state of the function for spin 1, $\alpha = 1/2R_d$, R_d is the radius of the deuteron, M is the deuteron mass, τ is the characteristic time and r is the distance between the proton and neutron. Considered as a whole the deuteron is a particle of spin 1. Hence it may be assumed that the part of the deuteron wave function which depends on its motion as a whole is transformed by a Lorentz transformation for the irreducible representation for spin 1, for example the representation given by Shirokov.[5] The part of the wave function which describes the relative motion is a scalar in the sense of the Lorentz transformation. Hence in the system in which the deuteron moves as a unit with a 4-velocity u_μ its wave function is of the form:

$$\varphi_i = \xi_i \exp(ip_\mu x_\mu)\sqrt{\alpha/2\pi}\exp\left(-\alpha\sqrt{y_\mu^2}\right)/\sqrt{y_\mu^2}.$$

Here $p_\mu = Mu_\mu$, $x_\mu^{p(n)}$ are the coordinates of the proton (neutron), $x_\mu = (x_\mu^p + x_\mu^n)/2$ and $y_\mu = x_\mu^p - x_\mu^n$. From the equality $y_\mu u_\mu = 0$, we have $y_0 = (u_i y_i)/u_0$, i.e., the characteristic contraction for a relativistic particle. The amplitude for the elastic scattering of the deuteron is written in a way similar to that used in reference 3. The only difference is that in place of the expression $\exp(-2\alpha r)/r^2$, after some simple transformations we obtain

$$\frac{\exp(-\alpha r)\exp\left(-\alpha\sqrt{r^2+\lambda^2 z^2 - 2\lambda z(\rho\cdot\nu)}\right)}{r\sqrt{r^2+\lambda^2 z^2-2\lambda z(\rho\cdot\nu)}}.$$

Here ν is a unit vector parallel to the projection of the velocity of the scattered deuteron on the plane perpendicular to the axis of the beam (z-axis); $\kappa' = p_0\theta R$, where p_0 is the initial momentum of the deuteron; $\lambda = \kappa'(\mu v/cMA^{1/3})$; μ is the mass of the π meson; A is the atomic number of the target nucleus.

For a given κ' the difference from the nonrelativistic scattering amplitude is determined by the parameter $\eta = \mu v/cMA^{1/3}$. When A = 216 we have $\eta \sim 1/80$; on the other hand the non-relativistic distributions have been computed in references 1 – 4 with an accuracy $1/p^2 \sim 1/9$ (for the same value of A). Completely analogous arguments may be invoked for diffraction stripping. On this basis it can be shown that when $E_d \gtrsim 6$ Bev the earlier formulas for diffraction scattering and stripping still apply.

These considerations can also be applied to the process of diffraction production, for example the production of a charged π meson by a relativistic proton. The possibility of such a process was first indicated by Pomeranchuk and Feĭnberg.[6] In emulsions irradiated by protons with energies greater than several Bev (approximately 10 Bev), this effect can appear as the scattering of a relativistic particle. The nucleus on which the break in the track would occur would not undergo any change but the scattering angle would be large (cf. below). To estimate the angular and energy distributions of the π-mesons this process can be considered as the diffraction of a deuteron-like system consisting of the π meson and the neutron. Part of the time a proton is in the state $\pi^+ + n$. The binding energy for this state is approximately μc^2 while the wave function for the internal motion, at least at a distance $r \gtrsim \hbar/\mu c$, is essentially the same as the wave function for the deuteron. For this reason quantitative estimates can be made on the basis of the results found for deuteron splitting. The system spends only approximately 1/10 of the total time in the state described by this wave function but we can still estimate the total cross section. Since the masses of the π meson and the neutron are different it is necessary to apply the formulas for unequal masses used in reference 4. The energy and angular distributions of the emitted π-mesons should be given by Eqs. (14) and (15) of reference 4. In accordance with Eq. (14) the maximum lies at a π-meson energy $E_\pi \sim \mu E_p/M \sim E_p/7$ while the mean momentum transferred to the nucleus is of order μc. In simple scattering at this same angle the proton would transfer a momentum of approximately Mc to the nucleus, in which case the nucleus should disintegrate.

In conclusion the author wishes to thank E. L. Feĭnberg for discussions of this problem.

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SCATTERING OF 240-Mev AND 270-Mev NEGATIVE PIONS ON HYDROGEN

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THE elastic and exchange scattering of π^- mesons on hydrogen at 240 and 270 Mev energy was studied, using the π^- meson beam of the Joint Institute for Nuclear Research synchrocyclotron. The measurements were carried out by means of scintillation counters. Liquid hydrogen was used as the target.

The measured values of the differential cross sections are given in Tables I and II (in units of 10^{-27} cm^2/sterad).

If we assume that only the S and P waves take part in the scattering, then the angular distributions can be written in the form

$$d\sigma/d\omega = AP_0 + BP_1 + CP_2,$$

where P_0, P_1, and P_2 are the Legendre polynomials. The coefficients of the expression, found by means of the least-mean-square method, are given in Table III (in units of 10^{-27} cm^2/sterad).

The total cross sections for the interaction of π^- mesons with hydrogen at 240 and 270 Mev energy equal $(48.3 \pm 3.3) \times 10^{-27}$ cm^2, and $(36.5 \pm 2.4) \times 10^{-27}$ cm^2 respectively.

TABLE I

(240±7) MeV			
$\vartheta^\circ_{c.m.s.}$	$\left(\frac{d\sigma}{d\omega}\right)_{\pi^- \to \pi^-}$	$\vartheta^\circ_{c.m.s.}$	$\left(\frac{d\sigma}{d\omega}\right)_{\pi^- \to \gamma}$
39.9	1.60±0.16	19.7	9.91±1.21
58.7	1.40±0.12	38.8	7.96±0.93
76.3	1.01±0.09	57.2	6.63±0.77
97.8	0.82±0.09	74.5	4.53±0.53
117.1	0.89±0.08	95.7	4.05±0.49
138.6	1.48±0.12	114.9	3.47±0.43
158.1	1.97±0.19	136.8	3.58±0.51
		157.0	4.56±0.60

TABLE II

(270±7) Mev			
$\vartheta^\circ_{c.m.s.}$	$\left(\frac{d\sigma}{d\omega}\right)_{\pi^- \to \pi^-}$	$\vartheta^\circ_{c.m.s.}$	$\left(\frac{d\sigma}{d\omega}\right)_{\pi^- \to \gamma}$
40.6	1.40±0.13	20.0	7.78±0.94
59.6	1.17±0.11	39.6	6.19±0.73
77.3	0.83±0.08	58.1	4.90±0.59
98.8	0.60±0.06	75.5	3.42±0.41
117.9	0.77±0.08	96.8	2.52±0.32
139.3	1.09±0.10	115.9	2.31±0.30
158.4	1.56±0.16	137.6	2.65±0.36
		157.4	3.10±0.42

TABLE III

	240 Mev			270 Mev		
	$\pi^- \to \pi^-$	$\pi^- \to \gamma$	$\pi^- \to \pi^0$	$\pi^- \to \pi^-$	$\pi^- \to \gamma$	$\pi^- \to \pi^0$
A	1.28±0.046	5.12±0.22	2.56±0.11	1.04±0.039	3.73±0.18	1.86±0.09
B	0.23±0.089	2.72±0.41	1.82±0.27	0.27±0.077	2.35±0.31	1.53±0.20
C	0.93±0.12	2.30±0.50	2.18±0.47	0.79±0.094	2.01±0.36	1.81±0.32

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