noted that saturation of the electronic resonance is not necessarily required.

It should be possible to apply this effect toward obtaining polarized samples for the study of nuclear level decay schemes. Another consequence is that it is possible to measure nuclear relaxation times in systems where the nuclear resonance cannot be observed because of the strong and fluctuating local magnetic field at the nucleus due to the electrons.

It is a pleasure to thank the members of the solid state group at the University of California for many stimulating discussions.

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Nuclear Electric Quadrupole Moment of Na^{23}

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IT has recently been reported by Sagalyn[1] that the nuclear electric quadrupole moment of Na^{23} is $+0.1\times10^{-24}$ cm^2. On Mayer's single-particle level scheme, there are three possible configurations for the ground state of Na^{23}. They are $[(d_{5/2})^3]_{3/2}$, $[(d_{5/2})^2 s_{1/2}]_{3/2}$, $[(d_{3/2})^3]_{3/2}$. The actual level order here, as given by Mayer,[2] is $d_{5/2}$, $s_{1/2}$, $d_{3/2}$. The last assignment, though giving a positive Q, is extremely improbable, because of the large departure of the observed magnetic moment from the Schmidt limit. Mayer herself preferred the first assignment, especially because a calculation of μ with jj coupling gives for this configuration a value of 2.87 nm, in fairly good agreement with the experimental value of 2.22 nm. However, as has been shown by Sagalyn,[1] the quadrupole moment in this configuration with jj coupling comes out to be zero. Hence the $(d_{5/2})^3$ configuration also cannot be accepted. We are thus left with the second alternative. Calculations for both magnetic and quadrupole moments have been carried out for this configuration with jj coupling. The wave functions for the $(d_{5/2})^2$ configuration are calculated by the method of Gray and Wills[3] and the total wave function for $(d_{5/2})^2 s_{1/2}$ is then antisymmetrized by the method given in Condon and Shortley.[4] The $(d_{5/2})^2$ state is coupled with the $s_{1/2}$ state to give the observed spin of 3/2. The result gives

$$\mu = 1.78 \text{ nm},$$

$$Q = +(8/35)\langle r^2\rangle_{\text{Av}} = +0.041\times10^{-24} \text{ cm}^2,$$

where $\langle r^2\rangle_{\text{Av}}$ is calculated from the formula $r=1.5A^{\frac{1}{3}}\times10^{-13}$ cm. Thus the observed magnetic dipole and electric quadrupole moments of Na^{23} are found to support the assignment $[(d_{5/2})^2 s_{1/2}]_{3/2}$ for its ground state.

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K Mesons and a Charged Hyperon Produced by 3-Bev Protons in Emulsions*

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A GROUP of glass backed plates and pellicles were exposed inside the Cosmotron to 3-Bev protons. The proton flux was greatly reduced from the normal operating intensity, and the plates were exposed to about 5 pulses from the Cosmotron. The proton track density in the plates is about 5×10^5 tracks/cm^2.

The emulsions were area scanned with an over-all magnification of about 100×, looking for slow heavy mesons, hyperons, and bound Λ^0 particles. In this note we describe three events which are interpreted as two K mesons and a hyperon. These three events were found in 4.5 cc of emulsion. A detailed description of bound Λ^0 particles will be given elsewhere.

The essential characteristics of the three events are given in Table I.

A photograph of the production and decay of particle K_1 is shown in Fig. 1. The track of the K meson is 7000 microns long and stops in the same plate, giving rise to a secondary track which is nearly in the plane of the emulsion and is 24 000 microns long in the same plate. The ionization along the secondary track was measured by blob counting and was compared with 3-Bev proton tracks at the same depth in the emulsion. The ionization of the secondary particle was found to be 1.08 ± 0.06 times that of the 3-Bev protons. The scattering parameter, $p\beta$, of the secondary particle was found to be 180 ± 13 Mev/c by using cells of 200 microns. The kinetic energy of the secondary particle is 121 ± 9 Mev, 109 ± 8 Mev, or 180 ± 13 Mev if we assume it to be a μ meson, a π meson, or an electron respectively. The expected relative ionization,[1] compared with 3-Bev protons, is 1.1 ± 0.02 for a μ meson and 1.2 ± 0.02 for a π meson. The measured ionization and multiple scattering strongly indicate that the secondary particle is a μ meson or an electron. If the secondary particle is assumed to be a π meson, the expected ionization differs from the measured value by about two standard deviations. The mass of the K_1 particle was found to be $850\pm150m_e$ by using the constant sagitta method.[2,3] The event is consistent with the decay of a meson of

TABLE I. Characteristics of heavy mesons.

Event	Range of primary (microns)	Mass of primary (m_e)	Range of secondary (microns)	Ionization ratio I/I_0	$p\beta$ of decay particle in Mev/c	Identity of secondary
K_1	7000	850±150	>24 000	1.08±0.06	180±13	μ or e
K_2	4400	920±200	>200	μ_1	...	...
Y_1	820	2300±1000	1783±20	(black)	191±1	p

mass about $900m_e$ into a μ meson and a single neutrino or into an electron and two neutrinos.

The K_2 particle entered the emulsion from the glass backing and stopped in the plate after 4.4 mm. The decay track dips steeply in the emulsion, therefore no reliable measurements can be obtained. The ionization is about minimum. The measurement of the mass of particle K_2 by the constant sagitta method gives 920 $\pm 200m_e$.

A projection drawing of event Y_1 appears in Fig. 2. The increase in the amount of small angle scattering, the absence of gaps and δ rays along track Y^+ near point A strongly implies that the particle stopped at point A (Fig. 2). The mass measurement along track Y^+, by the constant sagitta method, gives a value of $2300\pm 1000m_e$. The secondary particle p stopped in the adjacent emulsion, and the characteristics of the track indicate that it is a proton. The total range of the proton is 1783±30 microns, corresponding to an energy

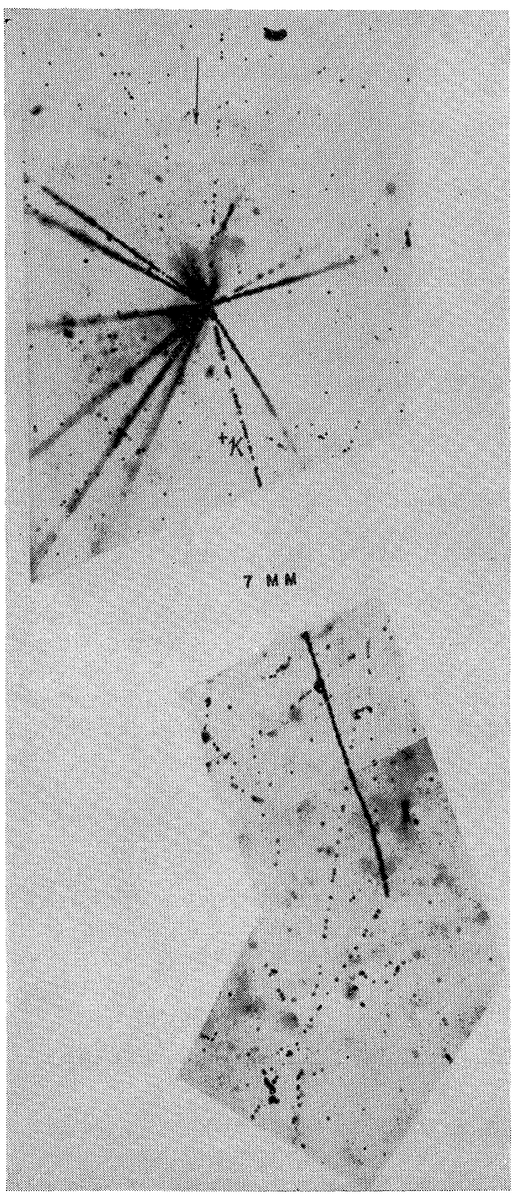

FIG. 1. The production and decay of a K meson by a 3-Bev proton is shown in the projection drawing.

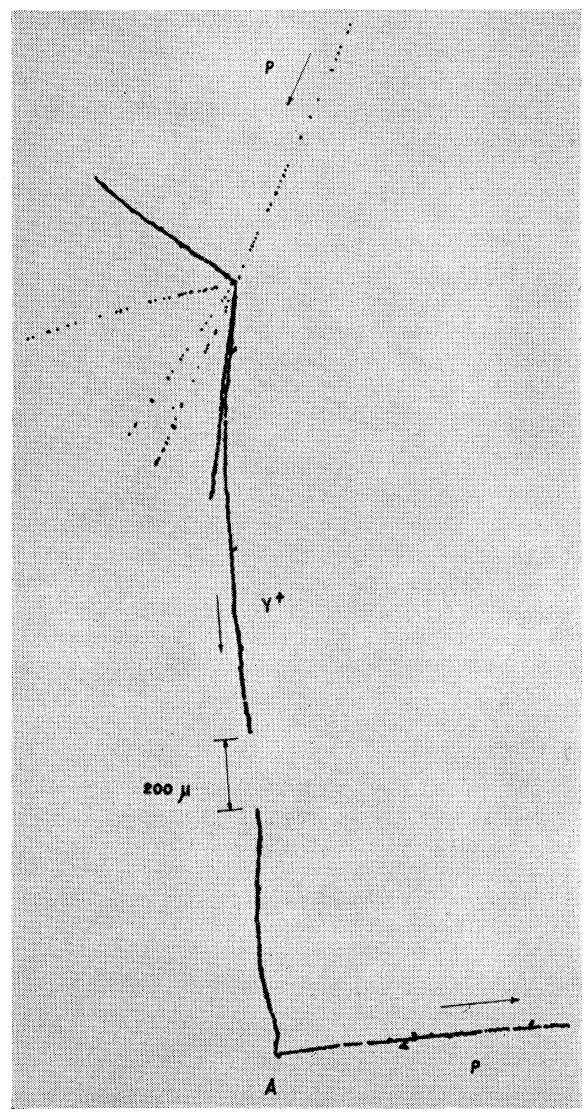

FIG. 2. A charged hyperon (Y^+) is produced in the collision of a 3-Bev proton. The hyperon appears to have stopped at point A and decayed into a proton.

of 19.5±0.2 Mev.[4] There are no associated low-energy electron or recoil tracks at point A (Fig. 2). The absence of a recoil and low energy electron in conjunction with the mass measurements along the primary make it improbable that the proton was ejected by the nuclear capture of a negative π or K meson. In terms of known decay schemes, it seems reasonable to interpret the event as the decay, from rest, of a charged hyperon[5] (Y^+) into a proton and a neutral π meson:

$$Y^+ \rightarrow p+\pi^0+Q.$$

The Q value for this reaction is found to be 117±2 Mev. From the measured Q value, the mass of the hyperon is found to be $2329\pm5m_e$. The Q value is in excellent agreement with two other similar events reported by the Genoa-Milan and the Padua groups.[6] In these two events, the proton energies were found to be 18.7±0.2 Mev and 18.5±0.3 Mev, respectively. The consistency in the ranges of the protons among the three events (the Genoa-Milan, the Padua event, and the above event) strongly indicate that these three hyperons decayed from rest and that only two particles were involved in the decay.

The authors are greatly indebted to the Cosmotron group for their assistance in exposing the plates and particularly to Dr. R. K. Adair for his continued interest and cooperation.

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Theory of Coulomb Excitation

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THE theory of Coulomb excitation has been considered earlier by many authors. Especially helpful for the interpretation of the experiments is a semiclassical calculation by Ter-Martirosyan.[1,2] In this theory the trajectory of the impinging particle is described by a classical hyperbolic orbit.

We have obtained a somewhat more accurate description of the process by approximating the Coulomb wave function, entering in the quantum-mechanical treatment, by means of the WBK method. The results of this calculation are very similar to the results of the semiclassical theory. The cross sections for electric dipole and electric quadrupole excitation are:

$$\sigma(E1)=\frac{2\pi^2 Z_1^2 e^2}{9\hbar^2 v_i^2}B(E1)g_{E1}(\xi), \tag{1}$$

$$\sigma(E2)=\frac{2\pi^2 m_1^2 v_f^2}{25 Z_2^2 e^2 \hbar^2}B(E2)g_{E2}(\xi), \tag{2}$$

with the following new definition of the parameter:

$$\xi=\alpha_f-\alpha_i=\frac{Z_1Z_2e^2}{\hbar}\left(\frac{1}{v_f}-\frac{1}{v_i}\right), \tag{3}$$

where Z_1e and Z_2e are the charges of the impinging projectile and the nucleus, respectively. The initial and final relative velocities are denoted by v_i and v_f, while m is the reduced mass. $B(E\lambda)$ is the reduced transition probability for electric 2^λ-pole radiation in the notation of Bohr and Mottelson.[3] The functions $g_{E\lambda}(\xi)$ are the same as those entering in the semiclassical expression.[1,2] For small excitation energies ΔE, the formulas (1), (2), and (3) reduce to the corresponding semiclassical formulas. We have then $v_f\sim v_i\sim v$, and

$$\xi=\frac{Z_1Z_2e^2}{\hbar v}\frac{\Delta E}{2E}. \tag{4}$$

The expression (1) for electric dipole excitation has been compared with the exact quantum mechanical formula[4]

$$\sigma(E1)=-\frac{128\pi^4}{9}\frac{Z_1^2e^2}{\hbar^2 v_i^2}B(E1)\left(\frac{\alpha_f}{\alpha_i}\right)^2 \times\frac{e^{2\pi\alpha_i}}{(e^{2\pi\alpha_i}-1)(e^{2\pi\alpha_f}-1)}\frac{d}{dx_0}|F(x_0)|^2,$$

where

$$x_0=-4\alpha_i\alpha_f/(\alpha_i-\alpha_f)^2, \tag{5}$$

and

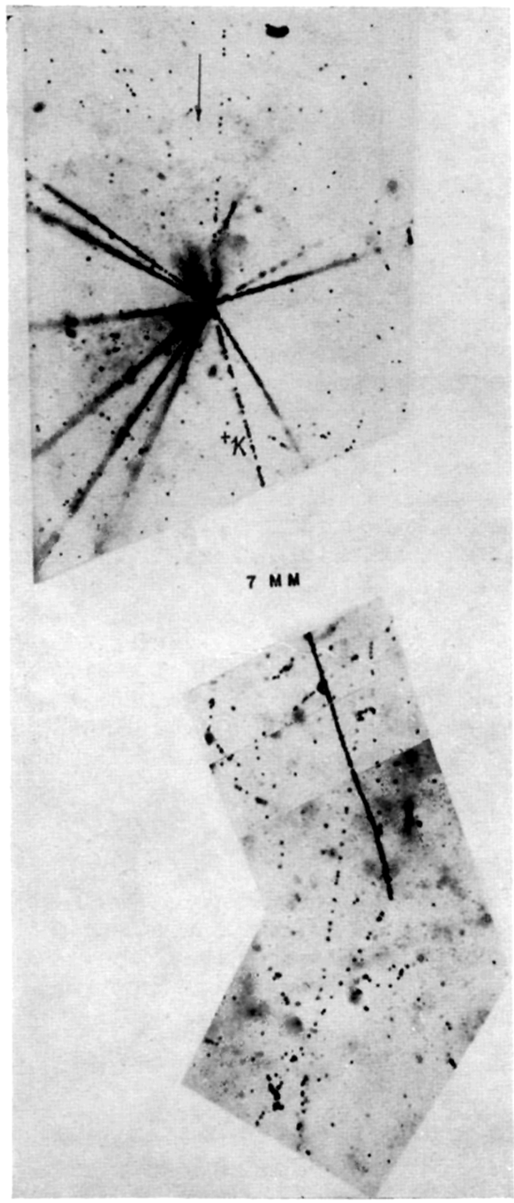
$$F(x_0)={}_2F_1(-i\alpha_i,\ -i\alpha_f,\ 1,\ x_0)$$

in terms of ${}_2F_1$, the ordinary hypergeometric function. In the range $\alpha_i\geqslant1$ and $0\leqslant\alpha_f-\alpha_i=\xi\leqslant1$, the WBK expression (1) agrees within 2 percent with the quantum mechanical calculation, which represents a considerable improvement over the semiclassical treatment.

In the case of the quadrupole excitation, no exact quantum mechanical treatment has been given, but the adequacy of the WBK treatment for the $E1$ case, suggests that (2) should also represent a good approximation when the effects resulting from penetration of the bombarding particle into the nucleus itself can be neglected.

Indeed, it is found that (2) satisfactorily represents all the experimental yield curves available to us at the present time.

Other kinds of electromagnetic excitations have also been considered and a detailed account of all the calcu-



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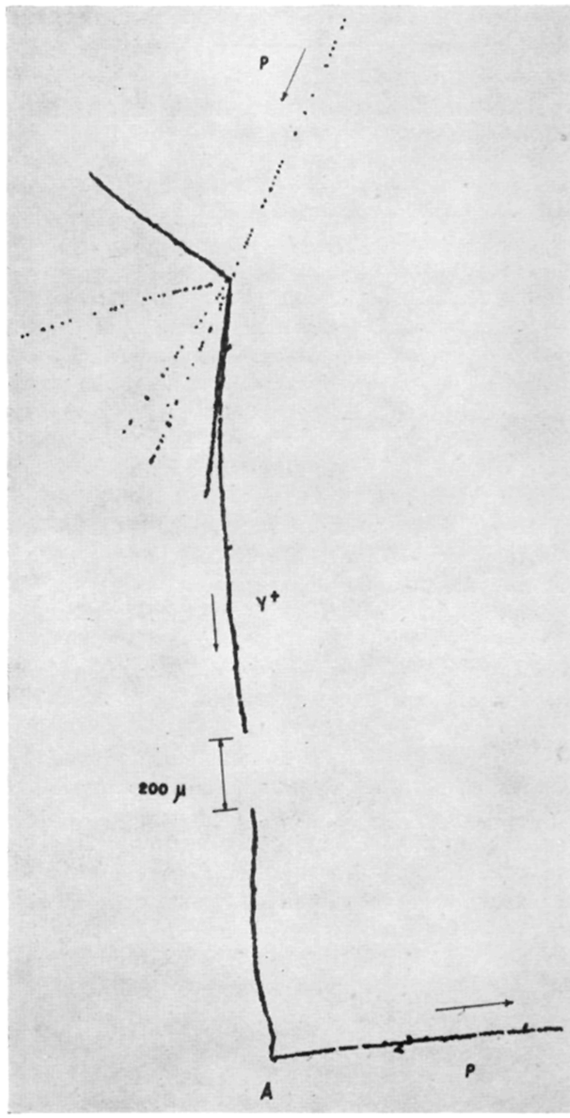

FIG. 2. A charged hyperon (Y^+) is produced in the collision of a 3-Bev proton. The hyperon appears to have stopped at point A and decayed into a proton.