therefore have been evaluated as explicit functions of W, and tabulated; in the notation of reference 8, $A_1=1/\mu_1(W)$, $B_1=\mu_2(W)/\mu_1(W)$. For $W=W_0$, $I_1(\theta)\sim\cos^2\theta-\cos^4\theta$, and, in fact, even for W down to $\frac{3}{4}W_0$, $I_1(\theta)$ still approximates to a $\cos^2\theta-\cos^4\theta$ distribution in that it has a pronounced maximum near 45° (and 135°). For example, when $W=9.4$ Mev the maximum occurs at 42° and $I_1(0°):I_1(42°):I_1(90°)=2.3:4.9:1.0$. Thus, if only the high energy β-particles are used in the $\beta-\alpha$-correlation experiment, the occurrence of a maximum near 45° in the angular distribution will be a definite criterion for the applicability of scheme (1), since $1+A_2\cos^2\theta$ can never have a maximum between 0° and 90°. If the distribution is anisotropic, but with no maximum between 0° and 90° (at high energies), then we know that scheme (2) applies. An isotropic experimental distribution would, as we have seen, be evidence for an excited Be^8 state of spin 0; it would not be quite conclusive evidence, however, for it could be that we have scheme (2) with the anisotropy of $I_2(\theta)$ too small to be detected. By selecting only the highest energy β-particles for the correlation, experiment, this latter possibility would be reduced to a minimum. Summarizing, then, we conclude that if the $\beta-\alpha$-angular distribution at high β-energies shows any correlation at all, the Be^{8*} has spin 2, and either scheme (1) or scheme (2) applies according as the distribution does, or does not, have a maximum between 0° and 90°. An isotropic distribution probably, but not certainly, means spin 0 for the Be^{8*}.

The work reported above was begun at the Atomic Energy Research Establishment, Harwell, England, in connection with proposed experiments on the $\beta-\alpha$-correlation in the Li^8 disintegration; the writer is indebted to Messrs. J. M. Cassels and T. H. R. Skyrme of Harwell for valuable discussion.

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The Problem of Using Scintillation Crystals as Proportional Counters for High Energy Particles*

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(Received January 22, 1951)

Up to about 10 Mev, close proportionality between the energy of incident particles and light output in scintillation counters is now a well established fact.[1] In the present investigation an attempt has been made to determine whether this proportionality still holds for high energy μ-mesons and whether the energy loss of these particles in the crystal would fit the theoretical formula of Bethe and Bloch.

Lead absorbers were used to select two energy ranges below the energy of minimum ionization including all particles (a) from 29 to 48 Mev, and (b) from 48 to 170 Mev. Particles with energies from 170 Mev upwards constituted a separate group. These energy ranges were selected to give an increase in the energy loss in equal steps (0.7 Mev/g/cm²).

The coincidence pulses of the fourfold Geiger-Müller counter telescope (Fig. 1B) initiated the sweep of an oscilloscope. The pulses from two RCA 5819 photomultipliers, viewing a cylindrical anthracene crystal (both diameter and length $1\frac{1}{4}$ in.), were delayed and appeared on the sweep together with delayed pulses from Geiger-Müller trays, which determined the range of the mesons through the lead absorbers. Geiger-Müller trays on each side of the telescope prevented shower particles from triggering the sweep.

The aperture of the arrangement was 0.08 steradians, giving an average counting rate of 8 pulses per hour. An additional 16.5-in. lead absorber on top was used to cut off μ-mesons below 580 Mev, thus increasing the counting rate in the ranges for low energies.

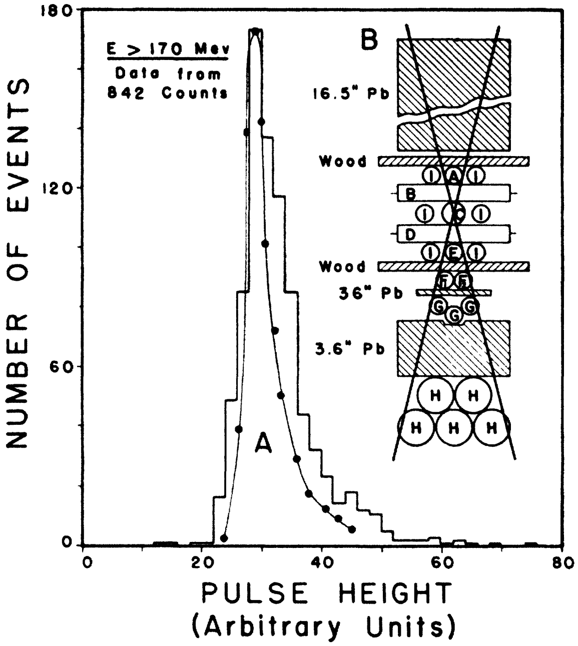

Fig. 1. (A) The histogram shows the distribution of pulse heights found for μ-mesons of energy greater than 170 Mev passing through the phosphor. The smooth curve is the distribution expected on the basis of Landau's theory. (B) Experimental arrangement.

As shown in Fig. 1A, μ-mesons of energy greater than 170 Mev (minimum ionization) passing through the crystal give rise to a pulse height distribution strongly peaked around the mean value of 30.3 Mev. Two conclusions can be drawn:

(1) Because of the rather small spreading out of the pulse height distribution (half-width 20 percent), it is immediately obvious that α-particles and other multiply-charged nuclei should be completely separable from mesons, protons, and electrons.

(2) A possible relativistic increase in energy loss for high energy mesons cannot be deduced directly, because of statistical fluctuations in the ionization process which, according to calculations performed by Landau,[2] are by no means negligible, mainly on account of δ-ray production. This impresses a characteristic skewness on the distribution curve, thus masking the relativistic effect which also tends to produce an appreciable asymmetry. However, some preliminary indication for such an increase might be deduced from the fact that Landau's curve, normalized to pulse height as shown in Fig. 1A, is definitely narrower than the actual distribution obtained by experiment. The difference between the two distributions beyond the maximum (for high energy losses) is quite outside the experimental error of the measurements.

This discrepancy cannot be explained by fluctuations only in the multiplicative effect of the phototubes, which under good conditions for light collection amount to about 5 percent and would certainly affect the distribution equally on either side of the maximum. However, such a difference can be satisfactorily explained on the basis of the Bethe-Bloch formula for ionization loss as corrected by Wick for the density effect, taking into account Wilson's energy spectrum for cosmic rays.

Further experiments are under way to separate, in more direct form, the statistical fluctuations from the expected relativistic rise in ionization. Some indication of an increase up to about 10 percent was reported in photographic plates.[3]

The pulse height distributions in the ranges below minimum ionization energy are broader (Fig. 2), owing to the fact that they result from the superposition of a great many curves similar to

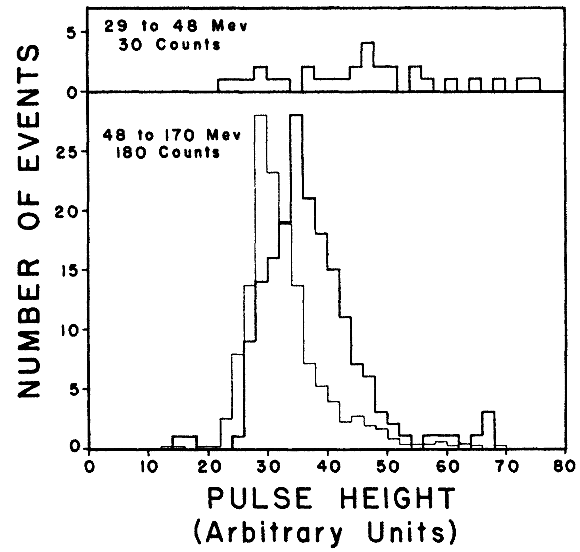

FIG. 2. Upper histogram: the distribution of pulse heights for μ-mesons of energies between 29 and 48 Mev [range (a)]. Lower histogram: the heavy curve shows the distribution of pulse heights for meson energies between 48 and 170 Mev [range (b)]. The light curve is the distribution of Fig. 1A, which is shown for comparison.

the one of Fig. 1A. This is a consequence of the continuous increase in energy loss throughout each energy range.

On the basis of the Bethe-Bloch ionization curve the mean increase in energy loss for μ-mesons (relative to the loss at minimum ionization) should be 20.5 percent for range (b) and 61 percent for range (a). As shown in Fig. 2, the experimental mean values are 22.8±2 percent and 54±7.5 percent above the experimental mean value for minimum ionization, for ranges (b) and (a), respectively. The corresponding shift of the distribution histograms in Fig. 2 to higher values of pulse height is clearly visible.

Knock-on electrons, accompanying μ-mesons and triggering the counter telescope, are necessarily in the range of minimum ionization energy. The pulses of minimum ionization, as shown in the top histogram of Fig. 2, are obviously due to such knock-ons.

In view of these results and by considering the energy range (b) as the most reliable one, proportionality between energy and pulse height within a limit of less than 5 percent seems to be strongly indicated for μ-mesons up to 170 Mev. This further indicates that for other particles one should also expect proportionality up to the respective energies of minimum ionization.

We are greatly indebted to Professor Marcel Schein for his constant interest in this investigation.

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* Assisted by the joint program of the ONR and AEC.

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The Effect of Electron-Neutron Interaction on Spectral Isotope Shifts

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(Received February 20, 1951)

HAVENS, Rainwater, and Rabi[1] have reported an electron-neutron interaction potential $V=5300\pm1000$ ev, assuming a square well of radius $r_0=2.8\times10^{-13}$ cm. This interaction may be expected to contribute to the isotopic displacement of spectral lines, particularly among the heavier atoms where the large nuclear charge results in a considerable electron density for s electrons at the nucleus.

The relativistic density for s electrons near a point charge Ze is given by[2,3]

$$P(r)=\frac{2(1+\rho)\psi^2(0)}{[\Gamma(2\rho+1)]^2}\left(\frac{2Zr}{a_0}\right)^{2\rho-2}=Ar^{2\rho-2},$$

where

$$\rho=(1-Z^2\alpha^2)^{\frac{1}{2}}$$
$$\alpha=e^2/\hbar c$$
$$a_0=\hbar^2/mc^2$$

and $\psi(0)$ is the nonrelativistic Schroedinger wave function for the electron at $r=0$. If one assumes that the additional neutrons of a heavier isotope are to be found primarily near the edge of the nucleus, then the contribution to the isotopic displacement for an s electron is

$$\epsilon=4\pi nAR^{2\rho-2}r_0^3V,$$

where R is the nuclear radius and n is the difference in atomic weight.

This may be compared with the isotope shift due to the change in nuclear radius.[2-4] If one assumes a uniform charge distribution throughout the nucleus, this shift is given by

$$\delta\Delta W=\frac{12\pi AZe^2}{(2\rho+1)(2\rho+3)}R^{2\rho-1}\delta R.$$

Upon inserting the values for r_0 and V, and using the empirical formula for the nuclear radius $R=1.5\times10^{-13}A^{\frac{1}{3}}$ cm, the ratio between the two contributions to the shifts is given by

$$\epsilon/(\delta\Delta W)\approx0.0122(2\rho+1)(2\rho+3)A^{\frac{1}{3}}/Z\text{ cm}^{-1}.$$

For zinc ($A=64$, $Z=30$) this ratio is about 0.024; it decreases with increasing atomic number. In deuterium, the $2S$ level would be shifted by 0.36 Mc due to the interaction.

The above calculations have not considered the distortion of the wave function due to the departure of the potential from a coulomb field. This effect has been treated in the case of the displacements due to the change in nuclear radius,[3,5] and has been found to reduce the shifts by a factor possibly as small as 0.5. A similar correction factor would be expected in the case of the electron-neutron interaction.

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Magnetic Resonance Absorption in Antiferromagnetic Materials

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THE microwave resonance absorption technique at 3.2-cm wavelength has been used to study the magnetic resonance absorption in MnS, MnO, and MnSe, which have Curie points at −75°C, −151°C, and −123°C,[1] respectively.

In the present experiment the specimen, in a form of a thin disk, was mounted at the bottom of a rectangular resonant cavity, which forms one arm of the microwave bridge and is made of transparent quartz plate, whose inside surface is coated with silvered thin copper plate. The relative magnetic absorption was obtained by observing the Q-value of the cavity, changing the dc magnetic field which was applied orthogonally to the rf magnetic field by an electromagnet.