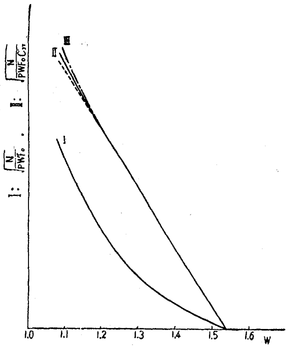

FIG. 2. Curve I is the Fermi plot of the Rb^{87} beta-spectrum. Curve II is the Fermi plot corrected by the third forbidden correction function C_{3T} for the tensor interaction in which the screening effect is taken into account. In Curve III the screening correction is not taken into account.

interaction between nucleons. These facts make us believe firmly the validity of Konopinski's forbidden theory in highly forbidden cases. Recently the Rb^{87} beta-spectrum was measured by Curran, Dixon, and Wilson,[3] and it was found to be quite different from the allowed shape.

Since the known spin and magnetic moment suggest that the configurations of Rb^{87} and Sr^{87} are $(p_{3/2})^{-1}$ and $(g_{9/2})^{-1}$, respectively, the Rb^{87} beta-decay is expected to be third forbidden with a spin change of three and a parity change.

The nT spectrum involves contributions from two matrix elements $Q_n(\beta[\boldsymbol{\sigma}\times\mathbf{r}],\mathbf{r})$ and $Q_n(\beta\boldsymbol{\alpha},\mathbf{r})$, and also from the matrix element $Q_{n+1}(\beta\boldsymbol{\sigma},\mathbf{r})$, but a rough estimate shows that the contribution from the matrix element $Q_{n+1}(\beta\boldsymbol{\sigma},\mathbf{r})$ is comparatively small.

Therefore, we only take into account the contributions from the matrix elements $Q_n(\beta[\boldsymbol{\sigma}\times\mathbf{r}],\mathbf{r})$ and $Q_n(\beta\boldsymbol{\alpha},\mathbf{r})$. They are, in the terminology of Greuling,[4]

$$\begin{aligned} C_{3T}=&\Sigma_{ij}|Q_{ij}(\beta[\boldsymbol{\sigma}\times\mathbf{r}],\mathbf{r})/3!|^2 f(W)\\ &-\Sigma_{ij}[\{Q_{ij}(\beta[\boldsymbol{\sigma}\times\mathbf{r}],\mathbf{r})/3!\}Q_{ij}^*(\beta\boldsymbol{\sigma},\mathbf{r})/3!+\text{c.c.}]g(W)\\ &+\Sigma_{ij}|Q_{ij}(\beta\boldsymbol{\alpha},\mathbf{r})/3!|^2 h(W). \end{aligned}$$

It was shown by Longmire and Messiah[5] that the ratio

$$\rho=Q_{ij}(\beta\boldsymbol{\alpha},\mathbf{r})/Q_{ij}(\beta[\boldsymbol{\sigma}\times\mathbf{r}],\mathbf{r})$$

is independent of M, M', i, $j\cdots$ and is real. Consequently,

$$C_{3T}=\Sigma_{ij}|Q_{ij}(\beta[\boldsymbol{\sigma}\times\mathbf{r}],\mathbf{r})/3!|^2\{f(W)-2\rho g(W)+\rho^2 h(W)\}.$$

To obtain F_0, F_n in $f(W)$, $g(W)$, and $h(W)$ which are given in Greuling's paper, we must calculate the complex Γ-function, and we calculate the latter according to Martin,[6]

$$\begin{aligned} \ln R=&\ln\Gamma(x+n)-\tfrac{1}{2}y^2\psi'(x+n)+\tfrac{1}{4}!y^4\psi^{(3)}(x+n)-\cdots\\ &-\tfrac{1}{2}\ln[x^2+y^2][(x+1)^2+y^2]\cdots[(x+n-1)^2+y^2], \end{aligned}$$

where $R=|\Gamma(x+iy)|$, n=integer, and $\psi^{(m)}(x)$ are poly-gamma functions.

The results are shown in Fig. 1. With the following ratio of the matrix elements, $\rho=4.2$, we obtain a good fit for C_{3T} to the experimental spectrum from about 100 kev to the upper limit of 275 kev (Fig. 2). In the region of energy below 100 kev we took into account the screening correction according to Longmire and Brown.[7] The values of $F(W-D_0)/F(W)$ are shown in Table I. The result is shown in Fig. 2. The slight shift in energy of 50 kev seems to be within the uncertainty of experiment.

However, it should be noted that the shift may be due to the "internal bremsstrahlung" electron.[8] The calculation of the "internal bremsstrahlung" electron correction is now in progress. The C_{3V} spectrum is different from the C_{3T} spectrum by only one small term B_n in the terminology of Greuling. As the contribution from B_n is so small, we obtain a good fit for C_{3V} to the experimental spectrum, too. On the other hand, all other matrix elements in the 1st, 2nd, and 3rd forbidden cases fail to explain the Rb^{87} spectrum.

TABLE I. The screening correction.

Wmc^2	1.1	1.2
$F_0(W-D_0)/F_0(W)$	1.04	1.01
$F_1(W-D_0)/F_1(W)$	1.05	1.02
$F_2(W-D_0)/F_2(W)$	$\sim$1.06	1.02
$F_3(W-D_0)/F_3(W)$	$\sim$1.06	1.02

We calculate the ft value and obtain $ft=4.2\times10^{16}$ where $t=6\times10^{10}$ yr, and the f value (=0.77) is obtained by graphical integration.

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Possible Influence of κ-Mesons on the Underground Cosmic Radiation

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THE existence of many heavy mesons in high energy nuclear events calls for an improvement of the previous theories of the underground μ-mesons, based only on the existence of the π-meson. In fact, μ-mesons may be divided in two categories: Some μ-mesons, which we call μ_κ, come directly from heavy mesons of the κ-type;[1] the others, which we call μ_π, come from π-mesons either directly, or through heavy mesons like V^0 or τ. Since heavy mesons have great masses and short lives relative to the π-meson, these two classes may be discriminated from each other, especially by the study of the thermometric coefficient.

Underground cosmic radiation seemed to have been correctly explained in terms of μ-mesons, on the basis of a 1.7 power law integral source-spectrum for the π-mesons, competition between absorption of the π-mesons in the atmosphere and $\pi-\mu$ decay, and electromagnetic losses for the corresponding μ's.[2] However, the recent discovery of μ-meson energy losses of nuclear origin[3] seems, in spite of the experimental uncertainties, to result in too low a vertical intensity of μ-mesons at great depths.[4] The vertical intensity of μ_π's at a depth d is:

$$I_\pi=\int_{E(d)}^{\infty}E^{-\gamma-1}(I+E/B)dE,$$

with $B=Lm_\mu(\rho\tau_\pi)^{-1}\simeq140$ Bev; L=mean free path of nucleons and π-mesons, taken as 125 g/cm^2; m_μ=mass of the μ-meson $=216\ m_e$; ρ=specific weight of the air at the absorption mean height; τ_π=mean life of π-mesons in their rest system$=2.6\times10^{-8}$ sec; c=velocity of light; γ=spectrum exponent$\simeq1.7$; $E(d)$=minimum energy required from a μ-meson to reach the depth d.

On the other hand, since κ-mesons are not absorbed in the atmosphere up to very great energies, because of their mass, 1200 m_e, their short life-time and their possibly weak nuclear interaction,[5] the intensity of the μ_κ's is:

$$I_\kappa=\int_{E(d)}^{\infty}E^{-\gamma-1}dE.$$

The above relations are true if all nuclear mesons are produced according to the same power law; this power spectrum is conserved under any decay at high energies.[6] Though the experimental uncertainties are great, a mixture of μ_π and μ_κ giving a vertical intensity $I=\alpha I_\pi+\beta I_\kappa$, with $\alpha+\beta=1$, might well explain both the vertical intensity experimental curve and the angular coefficient at 1700 m.w.e., with $\beta\simeq25$ percent. Since a departure of I from I_π is expected only at such high energies where one may hope β to be a constant, we shall take the same β for all depths.

A measurement of the thermometric coefficient at two different depths should provide a good test of the $\mu_\pi-\mu_\kappa$ mixture hypothesis, because the information thus obtained is, up to a certain ex-

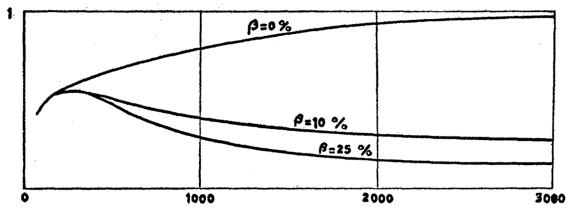

FIG. 1. $(\Delta I/I)\cdot(\Delta B/B)^{-1}$ is plotted against the depth d in m.w.e. for $\beta=0$ percent, 10 percent, 25 percent.

tent, independent of any assumptions about the energy losses of the μ's and the exponent of the power spectrum. A density change in the atmosphere produces a variation ΔB of B. Whereas I_κ is not affected, I_π varies, and one has:

$$\frac{\Delta I}{I}=\alpha\frac{\Delta I_\pi}{I}=\frac{\Delta B}{B}\cdot\frac{\alpha B^{-1}\int_{E(d)}^{\infty}E^{-\gamma}(1+E/B)^{-2}dE}{\alpha I_\pi+\beta I_\kappa}$$
$$=\Gamma\frac{\Delta T}{T}\cdot\text{function of } d.$$

T is the temperature recorded at one altitude; if the atmosphere was really isothermal, the correlation coefficient Γ would be unity. If two recordings were made simultaneously at two different depths, (about 250 and 1000 m.w.e.), the term $\gamma\Delta T/T$ would disappear and the ratio $[\Delta I(250)/I(250)]/[\Delta I(1000)/I(1000)]$ would give some indications about the proportion of μ_κ's in the ground, as can be seen from Fig. 1. Since this is known, it is possible to get back to the proportion of κ-mesons *versus* π (and τ, $V^0\cdots$), provided that some assumptions on the decay of these different particles are made. One should notice that the temperature coefficient cannot exceed 0.4 percent/°C, i.e., the value for $\beta=0$, $\Gamma=1$, $d=\infty$.

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A Ferroelectric Ammonium Metaphosphate*

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AMMONIUM phosphate prepared by the method of Tammann[1] is found to be ferroelectric in the range from −193 to +38°C. Conductivity obscures the ferroelectric hysteresis loop above 38°C, although the dielectric constant appears to climb fairly rapidly in the neighborhood of that temperature. No measurements were made below −193°C. The crystal is unstable in a dry atmosphere at room temperature, and must be stored near 0°C.

X-ray measurements demonstrate that the crystal has a monoclinic cell with $a=19.9_5$A, $b=6.91$A, $c=6.28$A, $\beta=98.5°$, space-group C_2 or Cm; and morphology indicates C_2. The density is 1.577 g/cm³. Although Tammann identified the compound as a monometa salt with 3 or 4 H_2O per molecule, a chemical analysis indicates between 5 and 6 H_2O, and x-ray and density measurements show 6 H_2O. The chemistry of the "metaphosphates" is unclear in general, and the precise nature of the compound must apparently await completion of the x-ray structure analysis now in progress. A Patterson projection on (001) indicates the existence of P_2O_6 groups.

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Angular Distribution of Pions Scattered by Hydrogen*

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THE angular distribution of the pions scattered by liquid hydrogen has been studied using the well collimated pion beams of the Chicago synchrocyclotron. A pair of 2-inch diameter scintillation counters define the incident beam which passes through them into a liquid hydrogen cell (Fig. 1). The scattered

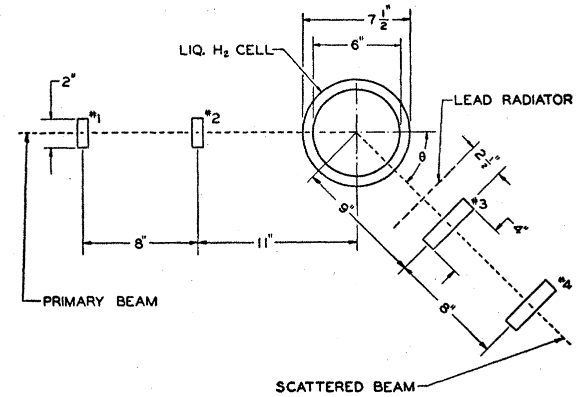

FIG. 1. Experimental arrangement.

particles are detected by two 4-inch diameter scintillation counters at suitable azimuth. A quadruple coincidence of all four counters requires a particle to pass through the first two counters and then to be scattered into the second pair. The quadruple coincidence rate, divided by the double coincidence rate of the first pair, which is recorded at the same time, gives the fraction of the beam which is scattered. The hydrogen cell was designed for rapid insertion and removal of the liquid hydrogen, to distinguish its effect from extraneous scattering. The charge exchange scattering was distinguished from the elastic scattering of negative pions by the insertion of a lead radiator in front of the second pair of counters, in order to enhance their sensitivity to gamma-rays.

The elastic scattering of positive pions at 110 Mev and 135 Mev, and both charge exchange and elastic scattering of negative pions at 135 Mev, were measured. The observations were taken at laboratory angles 45°, 90° and 135°.

The results, in the center-of-mass system, have been expressed in terms of the formula:

$$d\sigma/d\omega=a+b\cos\theta+c\cos^2\theta.$$

This angular distribution is expected when only s- and p-states contribute to the scattering. The values of the coefficients with their statistical errors are presented in Table I.

TABLE I. Coefficients for the differential cross sections.

Primary energy Mev	Process	a $10^{-27}\ \frac{\text{cm}^2}{\text{sterad}}$	b $10^{-27}\ \frac{\text{cm}^2}{\text{sterad}}$	c $10^{-27}\ \frac{\text{cm}^2}{\text{sterad}}$	$\int(d\sigma/d\omega)d\omega$ 10^{-27} cm²
110	$\pi^+\to\pi^+$	3.5 ±0.6	−4.6 ±0.8	7.2 ±1.8	74.5 ±5.4
135	$\pi^+\to\pi^+$	3.8 ±2.2	−6.8 ±2.7	17.5 ±6.6	121 ±19
135	$\pi^-\to\pi^-$	1.2 ±0.2	−0.1 ±0.3	0.3 ±0.7	16.2 ±2.3
135	$\pi^-\to\pi^0$	1.1 ±0.6	−2.5 ±0.5	6.3 ±1.9	40.6 ±2.3

The integrated cross sections listed in Table I are in good agreement with those obtained previously[1] by transmission measurements. For negative pions the contributions of exchange and non-exchange scattering should be added, plus a small contribution of about 0.8×10^{-27} cm² due to the inverse photo effect ($\pi^-\to\gamma$).