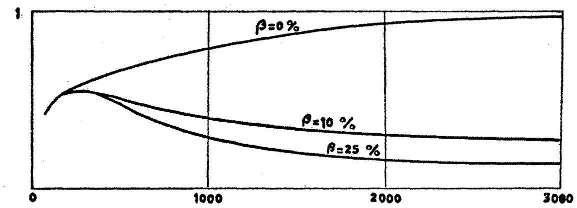


FIG. 1. $(\Delta I/I)\cdot(\Delta B/B)^{-1}$ is plotted against the depth $d$ in m.w.e. for $\beta=0$ percent, 10 percent, 25 percent.

tent, independent of any assumptions about the energy losses of the $\mu$'s and the exponent of the power spectrum. A density change in the atmosphere produces a variation $\Delta B$ of $B$. Whereas $I_\kappa$ is not affected, $I_\pi$ 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 $\Gamma$ 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 $\mu_\kappa$'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 $\kappa$-mesons *versus* $\pi$ (and $\tau$, $V^0\cdots$), 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 $\beta=0$, $\Gamma=1$, $d=\infty$.

[1] C. O'Ceallaigh, Phil. Mag. **42**, 1032 (1951); Crussard *et al.*, Compt. rend. **234**, 84 (1952). It is not impossible that $V^\pm$ and $\kappa$-mesons are the same particle: Armenteros *et al.* (private communication).
[2] S. Hayakawa *et al.*, Prog. Theoret. Phys. **4**, 287 (1949); **4**, 447 (1949); **5**, 844 (1950).
[3] E. P. George and J. Evans, Proc. Phys. Soc. (London) **A63**, 1248 (1950); Braddick, Nash, and Wolfendale, Phil. Mag. **42**, 1277 (1951).
[4] G. Wataghin and C. M. Garelli, Phys. Rev. **79**, 718 (1950).
[5] L. Michel and R. Stora, Compt. rend. **234**, 1257 (1952).
[6] A. Daudin, J. Phys. **10**, 65 (1949).

## A Ferroelectric Ammonium Metaphosphate*

R. PEPINSKY, C. M. MCCARTY, E. ZEMYAN, AND K. DRENCK
*Department of Physics, The Pennsylvania State College, State College, Pennsylvania*
(Received April 22, 1952)

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.

* Research supported by OAR.
[1] G. Tammann, J. prak. Chem. **45**, 431 (1892).

## Angular Distribution of Pions Scattered by Hydrogen*

H. L. ANDERSON, E. FERMI, D. E. NAGLE, AND G. B. YODH
*Institute for Nuclear Studies, University of Chicago, Chicago, Illinois*
(Received April 14, 1952)

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

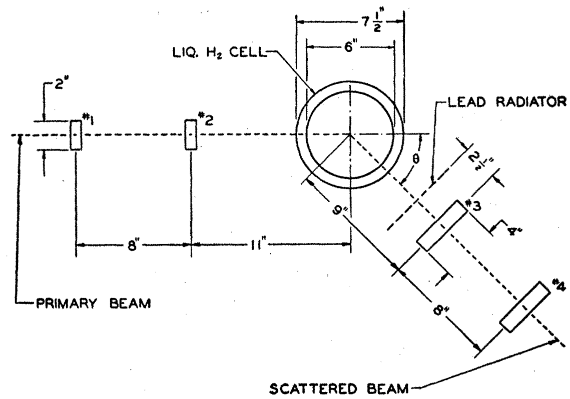


FIG. 1. Experimental arrangement.

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 | $\pi^+\rightarrow\pi^+$ | $3.5\pm0.6$ | $-4.6\pm0.8$ | $7.2\pm1.8$ | $74.5\pm5.4$ |
| 135 | $\pi^+\rightarrow\pi^+$ | $3.8\pm2.2$ | $-6.8\pm2.7$ | $17.5\pm6.6$ | $121\ \pm19$ |
| 135 | $\pi^-\rightarrow\pi^-$ | $1.2\pm0.2$ | $-0.1\pm0.3$ | $0.3\pm0.7$ | $16.2\pm2.3$ |
| 135 | $\pi^-\rightarrow\pi^0$ | $1.1\pm0.6$ | $-2.5\pm0.5$ | $6.3\pm1.9$ | $40.6\pm2.3$ |

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 $0.8\times10^{-27}$ cm² due to the inverse photo effect ($\pi^-\rightarrow\gamma$).