TABLE I. Values of $\sin\theta/\cos^4\theta$ calculated without and with the betatron effect. These are compared with the result obtained from the experimental value of θ.

	$\theta=2\pi\nu t$	$\sin\theta/\cos^4\theta$
Calc. without betatron effect	29.9°	0.88 ±3.3%
Calc. with betatron effect	33.0°	1.10 ±3%
Experimental result	33.4°	1.130±4.3%

r_0 = Target radius (96 cm ±1 percent).
H_0 = Maximum magnetic field at the target (11719 gauss ±1 percent).

(c) Betatron action resulting from field flux linking the orbit. This effect is found by numerically integrating the field plot from $r=0$ to $r=r_0$, yielding an additional energy loss correction

$$\dot{E}_{\text{betatron}}=er\dot{H}(0.20\pm0.01). \qquad (5)$$

Thus, inserting Eqs. (3), (4), and (5) into Eq. (2), letting $H=H_0\cos\theta$, where $\theta=2\pi\nu t$, and using Eq. (1), there results

$$\frac{\sin\theta}{\cos^4\theta}=\frac{1}{3\pi(1-0.20)}\left(\frac{E_0}{mc^2}\right)^3\frac{r_ec}{r_0^2\nu}, \qquad (6)$$

where r_e is the classical electron radius (2.82×10^{-13} cm); r_0 is the target radius; E_0 is the maximum electron energy at the target; ν is the magnet excitation frequency; m is the mass of the electron; and c is the velocity of light.

It is interesting to note the large betatron effect present during the entire magnetic cycle, even though the flux bars saturate at approximately 80 gauss. However, the decreasing portion of the magnetic cycle yields the energy loss given by Eq. (5).

The time when the x-ray signal vanishes is experimentally found to be $t=2900\pm50$ microseconds. (See Fig. 1.) The difference between the calculated and experimental value of $\sin\theta/\cos^4\theta$ is 2.7 percent and is seen to be within the assigned experimental error. From the results in Table I, there seems little doubt of the validity of the classical expression, Eq. (3), for electrons in the 300-Mev energy range.

Further theoretical study of the radiation problem has been made by Judd *et al.*[3] and by Olsen and Wergeland,[4] giving additional support to the classical interpretation of radiation by an electron in this energy range moving in a magnetic field.

The author wishes to thank Prof. E. M. McMillan for his suggestions and continued interest, and Drs. D. Judd, J. Lepore, M. Ruderman, and P. Wolff for many helpful discussions. It is also a pleasure to express thanks to Mr. G. McFarland and the crew of the synchrotron for help with this experiment, with particular thanks to Mr. G. Gauer.

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Associated Pairs of Particles in Cosmic-Ray Showers in Photographic Emulsions

J. Y. MEI* AND E. PICKUP
Physics Division, National Research Council, Ottawa, Canada
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IN an examination of 77 showers associated with stars in Ilford G emulsions exposed at 85,000 feet there appear to be more close groupings of tracks ($\lesssim1.5\times$ minimum ionization) than expected statistically. Such possible groupings have been mentioned qualitatively by Hornbostel and Salant.[1] Cosyns[2] has discussed pairs, triplets, etc., although Perkins[3] indicates that they could not confirm Cosyns' results. Recently Danysz, Lock, and Yekutieli[4] investigated a similar phenomenon for stars with two to six shower particles and suggested as a possible explanation an intermediate, very short-lived, neutral meson, mass $\sim550m_e$ (decaying into two charged pions with a small Q value).

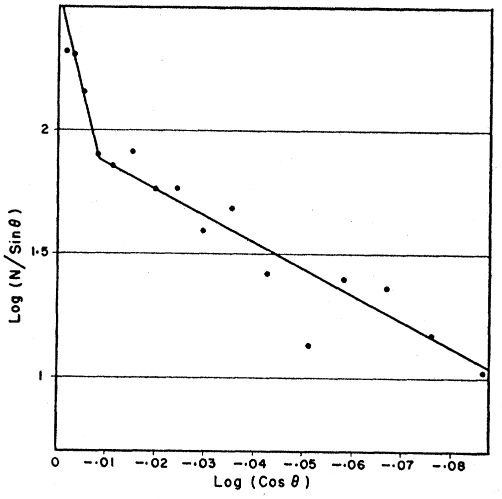

FIG. 1. Average angular distribution of particles in 77 showers. θ = mean angle for 2° interval; N = number of tracks in 2° intervals of polar angle; number of tracks per unit solid angle $=N/(4\pi\sin1°\times\sin\theta)$.

Our stars had an average of 10 shower tracks per star at <90 degrees to the primary direction, and stars with $\lesssim20$ and <6 shower tracks were excluded. Only pairs of tracks with $\lesssim4$ degrees separation were considered when they were outside any marked forward cone or appreciably off the probable forward direction. Measurements on two of the pairs indicated that the particles were lighter than protons.

TABLE I. Angular details of pairs. p = proton initiated star; n = no visible primary; n_s = number of shower particles; $\theta_{1/2}$ = half angle of shower cone; α = angle between pair and primary direction;[a] δ = half opening angle of pair. The last column gives the calculated statistical chance of the pair occurring in the particular star.

Primary	n_s	$\theta_{1/2}$	α degrees	δ	Estimated chance ($\times10^{-2}$)
p	6	24	7	1.5	16
p	11	5	5	0.8	13
p	8	6	5.5	1.6	20
p	11	29	4.6	1.3	0.36
p	10	14	9	0.8	7.3
p	8	17	36	1.6	1.9
p	16	13	12.5	0.45	2.2
p	11	13	30	1.1	2.5
?	10	30	51.5	1.1	0.07
p	14	26	41	1.6	1.7
n	13	4.5	28	1.6	7.3
n	17	14	37	2.0	5.4
p	14	2.5	21.5	1.5	10.7
n	9	16.3	53	1.75	0.12
p	9	13	10	1.25	17
p	10	5.5	5 5	1.5 1.5	7
p	10	11.6	6.75 24	1.1 2.5	3.4
p	21	9	40 13.5	1.5 0.7	0.26
n	10	5	8.5 9.0	0.3 1.5	4×10^{-3}
p	18	8.6	7 7 15	0.6 0.6 0.6	10^{-2}
p	17[b]	3	4.5 5.5 8 17 2.5	0.5 0.5 0.5 1.1 0.3 (triple)	5.5×10^{-5}

[a] Determined by cone symmetry where there is no visible primary.
[b] This may be a case of grouping within the main cone, and the calculated chance is very sensitive to the primary direction.

Table I gives details of the angular measurements,[5] the last column showing the statistical chance for the particular star, calculated using the average distribution curve for all the stars (shown in Fig. 1). If one excludes the last event, which may include forward cone particles, the mean calculated chance from 20 stars with pairs approximates 4×10^{-2}. Assuming these to be representative of all 77 stars, we would, therefore, expect about three chance pairs, whereas 25 pairs were observed. The number of individual cases with two or more pairs is somewhat greater than we would have expected from the total number of pairs, and more data are desirable.

If one assumes the effect to be real, it seems unlikely that it could be explained solely on the basis of secondary collision processes because of the small angles between pairs. It is possible that some are electron pairs from the suggested alternative neutral pion decay, $\pi^0\rightarrow$electron pair$+h\nu$. Dalitz[6] estimates $\sim$1 in 80 for this mode of decay compared with the usual decay into two photons. If 70 percent of the shower particles are pions and there are an approximately equal number of neutral, negative, and positive pions, there will be $\sim$260 neutral pions for the 77 stars and thus about three electron pairs directly from neutral pion decay. Whether such electron pairs do occur in stars is not known at present.[7]

Another possibility is the decay of short-lived neutral mesons of mass $\sim 550m_e$.[4] Our results are insufficient to confirm this, and in any case the selection of pairs with small angles means that the Q value obtained, assuming such a decay, would be small and insensitive to the energy of the pions unless this were very unevenly balanced. If the pairs originated in this way, the number of such neutral mesons would be about 10 percent of the number of neutral pions. Wentzel[8] has also discussed a mu-pair theory (e.g., neutral pion may be a bound state of negative and positive muons), but there is no evidence in stars for appreciable numbers of muons, which might then be expected.

Further work is obviously necessary to confirm these results.

* National Research Laboratories Postdoctorate Fellow.
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The Structure of Ammonium Chloride by Neutron Diffraction

G. H. Goldschmidt* and D. G. Hurst
Atomic Energy Project, National Research Council of Canada, Chalk River, Ontario, Canada
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RECENTLY we published neutron diffraction patterns of ND_4Cl at -180°C and room temperature.[1] Subsequent measurements here and at Oak Ridge[2] have failed to confirm our values for the structure factors of the (111) and (210) lines at room temperature. Our deduction that the room temperature phase is ordered depended largely on the strength of the (111) line. The new measurements give much weaker intensity. Consequently, our conclusions concerning the room temperature phase can no longer be sustained. Levy and Peterson[2] have deduced a disordered structure from their results.

The intensity of the (111) line at room temperature was the major error in our measurements. This line was small compared to the background, and it was not well resolved from the strong (111) line because of the aluminum windows of the cassette. The error in the (111) line of ND_4Cl probably arose through a false enhancement owing to the subtraction of a background curve in which the neighboring (111) and (200) aluminum lines were too large. Preferred orientation in the aluminum may have contributed to the effect.

TABLE I. Structure factors of ND_4Cl at 23°C (units of 10^{-12} cm).

hkl	(100)	(110)	(111)	(200)	(210)	(211)
F	1.35	(2.47)	0.35	0.98	0.37	1.34

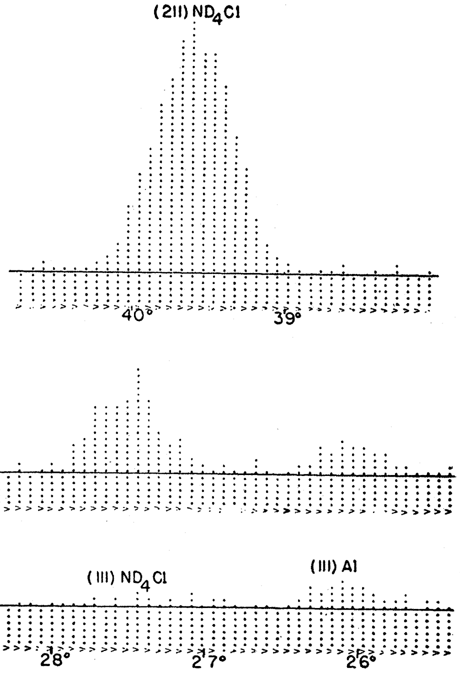

FIG. 1. Records of neutron scattering by ND_4Cl. Each dot represents 20 neutron counts. Each vertical column is recorded at a fixed angle for a predetermined number of neutrons incident on the specimen. The bottom record is the neighborhood of the (111) line at room temperature. Just above it is the same region at -170°C shifted slightly in angle to align the (111) peaks of aluminum. At the top is shown the (211) peak at -170°C. The incoherent background is shown by the horizontal lines.

Since the publication of the earlier results, the instrument has been greatly improved both as to resolution and methods of recording. In a new series of measurements by one of us, the (111) lines of aluminum and ND_4Cl were completely resolved. Only 0.004 inch of aluminum was in the beam, as compared to 0.010 inch previously. Samples of the records are shown in Fig. 1, where it is clear that the change in the (111) line between low and room temperatures is much larger than was found originally.

The structure factors obtained in the new measurements, normalized to 2.47×10^{-12} cm for the (110) line, are given in Table I.

We thank Dr. Levy and Dr. Peterson for bringing the discrepancy in the measurements to our attention.

* Now at the Clarendon Laboratory, Oxford, England.
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Soft Radiations from Am^{241}

J. K. Beling, J. O. Newton, and B. Rose
Atomic Energy Research Establishment, Harwell, Berks, England
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THE gamma- and x-radiation produced in the decay of the α-particle emitter Am^{241} have been examined over the energy range 5–120 kev by the proportional counter technique, using counters filled with argon, krypton, and xenon, respectively.