for detection of delayed radiation. By counting delayed coincidences in a small height interval against pulse height, a measurement of the spectrum of the delayed radiation is obtained. Figure 2 shows the result of such a measurement.

The scale of the pulse height dial Bas calibrated in energy units by using the K and L internal conversion lines of the 132-kev transition from the decay of the 22μsec. metastable state in Ta^{181*} and the K internal conversion line of the 247-kev transition from the decay of the 8×10^{-8} sec. metastable state in Cd^{111*}.[2] The latter isomeric state was detected using sources of Cd^{111*} (48 min.) produced by (n,γ) reaction on a sample of enriched Cd^{110}.

The solid curve is the conversion electron spectrum obtained after subtraction of the Compton electron distribution produced by the γ-rays and x-rays. The K and L conversion lines at 87 and 140 kev correspond to a (150 ± 10) kev transition. From the energy and half-life of this isomeric state the transition is probably electric octupole radiation or a combination of electric octupole and magnetic quadrupole radiation. It appears from this curve that no other γ-rays follow in cascade with the decay of Lu^{177*}.

The half-life of Yb^{177} as listed in the table of isotopes[3] ranges from 1.9 to 3.5 hr. A conventional half-life determination is complicated by the presence of the daughter activity Lu^{177} (6.9 day) and the Yb^{175} (100 hr.) present in the sources. By counting delayed coincidences at a fixed delay as a function of time, the coincidence rate decreases according to the decay of Yb^{177}. The decay was observed for 6 hr. and the half-life of Yb^{177} appears to be (1.8 ± 0.1) hr.

* This document is based on work performed under Contract No. W-7405, eng. 26 for the Atomic Energy Project at Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[1] McGowan, DeBenedetti, and Francis, Phys. Rev. **75**, 1761 (1949).
[2] Martin Deutsch and Donald T. Stevenson, Phys. Rev. **76**, 184 (1949).
[3] G. T. Seaborg and I. Perlman, Rev. Mod. Phys. **20**, 585 (1948).

Remarks on Non-local Spinor Field

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IN a recent letter to the editor,[1] it was shown that quantized non local fields could be so constructed as to represent assemblies of particles with the definite mass and radius. In a paper, which will appear very soon,[2] detailed account is given together with the elucidation of most of the points, on which the author was not very sure when he wrote the above letter.[1] However, there is still one point, which seems to the author to be unsatisfactory. Namely, in the case of non-local spinor field, we assumed the commutation relation

$$\beta_\mu[x^\mu, \psi]+\lambda\psi=0 \tag{1}$$

between the space-time operators x^μ and the non-local spinor operator ψ, in addition to the commutation relation

$$\gamma^\mu[p_\mu, \psi]+mc\psi=0 \tag{2}$$

between ψ and the space-time displacement operators p_μ. Further we assumed that γ^μ, β_μ, which were matrices with four rows and columns, were defined by

$$\left.\begin{array}{llll}\gamma^1=i\rho_2\sigma_1, & \gamma^2=i\rho_2\sigma_2, & \gamma^3=i\rho_2\sigma_3, & \gamma^4=\rho_3\\ \beta_1=\rho_3\sigma_1, & \beta_2=\rho_3\sigma_2, & \beta_3=\rho_3\sigma_3, & \beta_4=-i\rho_2\end{array}\right\}. \tag{3}$$

Now the difficulty was that, in contrast to (2), the relation (1) was not invariant with respect to the improper Lorentz transformation with the determinant -1, but was to change itself into the form

$$\beta_\mu[x^\mu, \psi]-\lambda\psi=0. \tag{4}$$

In the paper mentioned above,[2] a way of removing this difficulty was indicated, but was very unsatisfactory in that the number of components of the spinor ψ was to be increased from 4 to 8 without any immediate physical interpretation for the extra degree of freedom. It came to the author's notice very recently that the following alternative way was far more acceptable in that no extra components of the spinor were introduced. Namely, we take advantage of the antisymmetric tensor of the fourth rank with the components $\epsilon_{\kappa\lambda\mu\nu}$ which are $+1$ or -1 according as $(\kappa, \lambda, \mu, \nu)$ are even or odd permutations of (1, 2, 3, 4) and 0 otherwise.[3] Further we take into account the relations

$$i\beta_\nu=\gamma^\kappa\gamma^\lambda\gamma^\mu, \tag{5}$$

where $(\kappa, \lambda, \mu, \nu)$ are even permutations of (1, 2, 3, 4). Then (1) can be written in the form

$$\tfrac{1}{6}\sum_{\kappa\lambda\mu\nu}\epsilon_{\kappa\lambda\mu\nu}\gamma^\kappa\gamma^\lambda\gamma^\mu[x^\nu, \psi]+i\lambda\psi=0, \tag{6}$$

which is obviously invariant with respect to the whole group of Lorentz transformations. However, the invariance of (6) can be proved more explicitly by transforming ψ, while the matrices γ^μ are assumed to retain their prescribed forms as defined by (3) independent of the coordinate system. Namely, we can associate a linear transformation

$$\psi'=S\psi \tag{7}$$

with each of the Lorentz transformation

$$x_\mu'=a_{\mu\nu}x_\nu, \tag{8}$$

where S is a matrix with four rows and columns satisfying the relations

$$S\gamma^\mu S^{-1}=a_{\nu\mu}\gamma^\nu. \tag{9}$$

If we insert (7), (8) and (9) in (6) and take advantage of the fact that $\epsilon_{\kappa\lambda\mu\nu}$ are components of a tensor of the fourth rank, we obtain the commutation relation

$$\tfrac{1}{6}\sum_{\kappa\lambda\mu\nu}\epsilon'_{\kappa\lambda\mu\nu}\gamma^\kappa\gamma^\lambda\gamma^\mu[x'^\nu, \psi']+i\lambda\psi'=0, \tag{10}$$

which has the same form as (6).

It should be noticed, however, that the relation (6) is to be regarded as a unification of (1) and (4) rather than the mere reproduction of (1), because (6) must be identified with (4) in the coordinate system, which is connected with the original coordinate system by an improper Lorentz transformation with the determinant -1.

[1] H. Yukawa, Phys. Rev. **76**, 300 (1949).
[2] H. Yukawa, Phys. Rev. (to be published).
[3] The antisymmetric tensor $\epsilon_{\kappa\lambda\mu\nu}$ was useful for unifying the scalar and pseudoscalar fields as well as the vector and the pseudovector fields as shown by M. Schoenberg, Phys. Rev. **60**, 468 (1941).

Detection of Radioactive Atoms in the Air with Nuclear Emulsions

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IT has been shown recently[1] that atoms of a radioactive deposit remaining in the air from the decay of radon can be collected together with the dust from the air on a very small surface area of a glass plate. This is done by allowing air saturated with water vapor to flow (e.g., in a Owens-Běhounek dust-counter[2]) with a considerable velocity through a small jet toward this glass. This was demonstrated by exposing the glass in contact with a nuclear emulsion and by finding many tracks of alpha-particles after development of the plate in the small region, corresponding to the position of the dust-spot on the glass. We explained this phenomenon by at least partial adsorption of atoms of active deposit on dust particles.

New experiments with low activities of the air revealed that this method of collection of radioactive atoms from the air can be

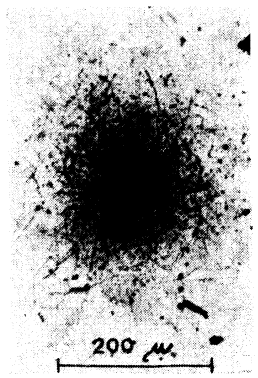

FIG. 1.

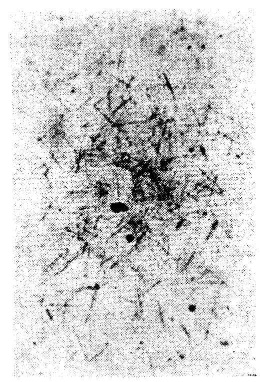

FIG. 2.

used as a sensitive indicator of radioactive contamination in the air, i.e., for air monitoring. Further simplification (which also represents a considerable increase of efficiency) was obtained by directing the stream of air toward a stripe of a nuclear plate and collecting dust together with radioactive atoms on the surface of the emulsion. By a suitable arrangement many air samples can be taken with the same stripe of the plate. Figure 1 shows a typical dust-spot on the surface of an Ilford C2 emulsion obtained by aspirating 125 cc of air containing 1.5×10^{-13} Curie/cc of radon and developed 4 hours after taking the sample. Figure 2 shows alpha-ray tracks on the same area of the plate after remova, of the dust-spot. In this area some 280 tracks were countedl which, assuming radioactive equilibrium in the air, would mean that nearly 20 percent of the atoms of active deposit were collected with the dust on the plate. This percentage may depend on the instrument used and/or on the dust-conditions in the air. The method seems capable of detecting quantities as low as 10^{-13} Curie of active deposit of radon.

Experiments have also been arranged in order to detect radioactive atoms in free atmospheric air. On dust-spots obtained by aspirating 1600 cc of free atmospheric air, on an average, 35 alpha-tracks were found. Most of them could be identified as alpha-particles of RaC. Assuming 20 percent efficiency, this would correspond to a radon concentration of 10^{-15} Curie /cc which is fairly consistent with the value found, for example, by G. Aliverti[3] by an iontometric method.

Using electron sensitive emulsions the method could be also applied for detection of artificial solid beta-emitters in the air. Low energy ends of electron tracks which would be most appropriate for counting could be found near the area of the dust-spot by energies up to 0.3 Mev.

The author would like to thank Dr. Běhounek for helpful discussions. A detailed account of the method with some applications will be published elsewhere.

[1] Č. Jech, Nature 163, 570 (1949).
[2] F. Běhounek and E. Effenberger, Gerlands Beitr. z. Geophys. 59. 74 (1942).
[3] G. Aliverti, Zeits. Geophysik 9, 16 (1933).

Neutron-Proton and Proton-Proton Cross Sections at 83 Mev

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CAMAC and Bethe[1] have shown that with central forces only and a square-well potential it was possible to obtain the observed cross sections for n–p scattering at 80 Mev provided that the range was 2.0×10^{-13} cm. Later Blatt[2] showed that the triplet range must be reduced to about 1.5×10^{-13} cm to fit the experimental values of coherent neutron scattering by crystals and by parahydrogen.

The following calculations have been performed, using square-well potentials, to test the possibility of obtaining the correct high energy scattering results by reducing the range of the central force in the triplet interaction. The tensor force has not been neglected but this involves increasing its range.

Two sets of force constants have been used:

	r_0	r_c	r_t	V_0	V_c	V_t
A.	2.8	1.6	3.08	11.9	39.3	10.04
B.	2.8	0	3.27	11.9	$v_1=4.49\times10^{11}$ cm^{-1}	9.62

where r is the range of the force in units of 10^{-13} cm, V is the depth of the well in Mev, and the subscripts 0, c, t denote singlet, central force triplet, and tensor force triplet interaction, respectively.

The singlet constants were chosen to fit the data on p–p scattering and the zero energy n–p cross section. The triplet constants were chosen to fit the binding energy, the quadrupole moment and the magnetic moment of the deuteron. Constants A were taken from the calculations of D. Padfield.[3] These agree reasonably well with results of coherent scattering of neutrons by parahydrogen and by NaH crystals since they give a zero energy triplet scattering length $a_1=-0.533$ as compared with an experimental value of -0.51 to -0.53.[4] B was considered as the limiting case of $r_c\rightarrow0$ with $V_c=\{(I/r_c^2)\sum v_n r_c^n\}\hbar^2/M$, where from requirements of continuity $v_0=\pi^2/4$. The constants in this case were calculated by F. Ledsham.[5]

Neutron-proton cross sections have been calculated at 83 Mev for symmetric and charged meson theory type of interactions and also for the mixture suggested by R. Serber in which only the even states interact. All phase calculations were performed exactly though the $({}^3D_3+{}^3G_3)$ and higher coupled phases were neglected. The total cross sections and the ratios of scattering at 90° and 180° are given in Table I and the differential cross sections in Fig. 1.

It would seem from these results that with the symmetric or charged theories there is no possibility of fitting the high energy data (at least with a square-well potential) by decreasing the central range r_c. This is shown in Fig. 2 where the total cross sections are plotted against r_c/r_t.[6] Though the high energy data might possibly be fitted by a Serber interaction, this has the disadvantage of introducing a new postulate, the amount of mixing of the symmetric and charged theories to account for the high energy scattering. Even then the single triplet range of 2.8×10^{-13} cm gives better results at 83 Mev though it does not, of course, fit the coherent scattering data.

Scattering of like particles.—Using the potential A, calculations have also been carried out for the p–p scattering at the same energy. To allow for the Coulomb interaction in the calculation of the nuclear phases, the equations were solved inside the well neglecting this potential and these solutions were fitted to Coulomb

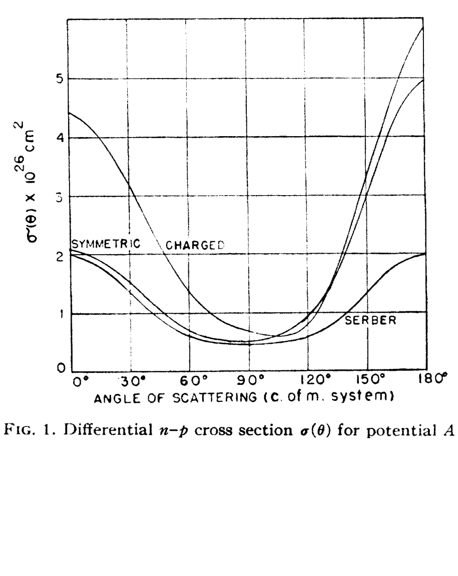

FIG. 1. Differential n–p cross section $\sigma(\theta)$ for potential A.

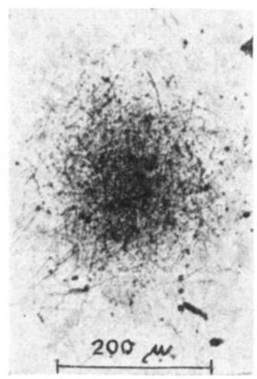

Fig. 1.

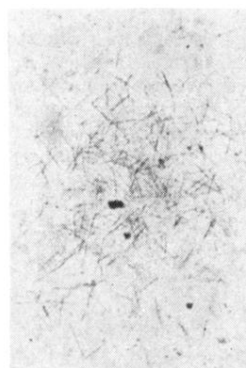

FIG. 2.