the magnitude of $E2$ in mixed transitions, making it impossible to relate the value of $E2$ to the deformation of the nucleus. However, an explanation of the increase in intensity of the direct transition with increased deformation can be given independently of the composition of the mixed transition 2+ – 2+. As was shown recently by Ford and Levinson[6], considerable increase in the probability of $E2$ transition may take place even in the case of relatively slight deformed nuclei. The intensity of the direct transition $E2$ can thereby exceed considerably the cascade transition, even if the latter has the nature of a pure transition $M1$. Apparently, also in this case, the relative intensity of the direct transition must increase with the increase in the deformation of the nucleus.

For some of the studied nuclei there are also known to exist higher excitations in addition to the two lower excited states having characteristics 2+. Inasmuch as the characteristics of the two lower excitations are equal, transitions from any higher level take place with the same change in spin and parity. If the multipole order of both transitions of such a pair were equal, the higher energy quantum, i.e., the transition to the first excited state, would always have the greater intensity. Actually, however, there are cases in which the inverse ratio of intensities is observed. Such a case was noted earlier by the authors[7] in the example of the Pt^{192} nucleus. Similar relation of intensities is observed for certain transitions of excited states of Pt^{194} and Os^{188}. The anomalous ratio of intensities can be connected with either additional selection rules (for example, type K forbiddenness[8]) or with the different nature of competition between the transitions.

---

1 M. Goldhaber and A. Sunyar, Phys. Rev. **83**, 906 (1951).

2. G. Scharff – Goldhaber, Phys. Rev. **90**, 587 (1953).

3 A. Bohr and B. Mottelson, Kgl. Don. Math – Fys. Medd. **27**, 16 (1953).

4 J. Blatt and V. Weisskopf, *Theoretical Nuclear Physics*.

5 I. S. Shapiro, J. Exptl. Theoret. Phys. (U.S.S.R.) 30, 975 (1956); Soviet Phys. JETP **3**, 779 (1956).

6 K. Ford and C. Levinson, Phys. Rev. **100**, 1 (1955).

7 Deliagin, Kuznetsova and Shpinel', Izv. Akad. Nauk SSSR Fiz. Ser. **20**, 909 (1956).

8 Alagie, Alder, Bohr and Mottelson, Kgl. Dan Mat. Fys. Medd, **29**, 9 (1955).

Translated by J. L. Herson
80

Dependence of the Polarization of (D + D) Neutrons on the Energy of the Deuterons.

I. I. LEVINTOV, A. V. MILLER, E. Z. TARUMOV, VN. SHAMSHEV
Institute of Chemical Physics, Academy of Sciences, USSR

(Submitted to JETP editor October 1, 1956)
J. Exptl. Theoret. Phys. (U.S.S.R.) **32**, 375-376 (February, 1957)

THE method described in detail in Ref. 1 made possible polarization measurements of (D + D) neutrons and their dependence on energy D. We had at our disposal a tabular accelerator of the Institute of Chemical Physics, Academy of Sciences, USSR, which yields deuterons of 1800 kev maximum energy.

Polarization measurements were made with thick and thin zirconium targets. In all measurements the turning center of the counters was located at an angle of 49° to the neutron beam and the turning angle $\varphi_\alpha = 22°$. The cut-offs of the five discriminator channels were equal to 0.4; 0.5; 0.6; 0.7; 0.8. Computations of the maximum polarization of (D + D) neutrons was made from the asymmetry data measured in channels with cut-offs 0.4 and 0.7. The channel with cut-off 0.4 corresponded to poorer geometry at which the widening of the solid angle $\Delta\Omega$ [see Eq. (1), Ref. 1] was equal to 19°. For the channel of cut-off 0.7 this angle was 11°. In all experiments the values of P_{max}, obtained for both these channels, were in satisfactory agreement. In the following presentation of results, the mean value of P_{max} for these two channels is used, while the experimental errors in P_{max} correspond only to the statistical inaccuracies of the measurements.

Results of asymmetry measurements with the thick target are shown in Table 1.

The maximum polarization of (D + D) neutrons computed from these data is shown in Fig. 1. Computations were made for energy $E_d = 2/3\ E_d^*$. Such averaging corresponds to the linear dependence of the effective cross section of the reaction on the deuteron energy and somewhat decreases the uncertainty existing in those experiments introduced by the thick target. The results shown in Fig. 1 should thus be regarded as the "exit" polarization for a thick target at the corresponding deuteron energies.

In the second series of experiments, a thin

TABLE 1

E_d (mev)		0.4	0.6	0.9	1.2	1.5	1.8
Pressure in counters (atm.)		1,034	1,143	1.263	1.380	1.449	1,566
Asymmetry R	0.4	1.119 ±0,029	1.170 ±0.028	1,141 ±0.016	1.119 ±0.011	1,125 ±0.013	1,106 ±0.011
	0,7	1.228 ±0.045	1,221 ±0,042	1.249 ±0,039	1.284 ±0.021	1,288 ±0.027	1,248 ±0.022

zirconium target (150 kev) was used. With prolonged bombardment of the target by D ions a redistribution takes place in the deuteron layer and a change in the thickness of the target. For this reason thin targets were replaced after 20-30 hours of operation.

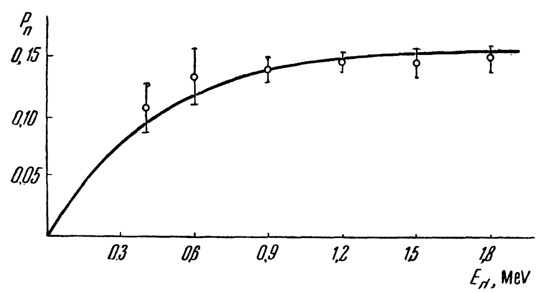

FIG. 1. "Exit" polarization of (D + D) neutrons for angle θ_n (lab) = 49° obtained from measurements using a thick target for various deuteron energies E_d.

Results are shown in Table 2 of asymmetry measurements in the conducted experiments, and values are given in Fig. 2 of P_{max} for (D + D) – neutrons computed from these data. In the same Figure are shown results of measurements by Meir, Scherrer and Trumpy[2] for E_d = 600 kev (target

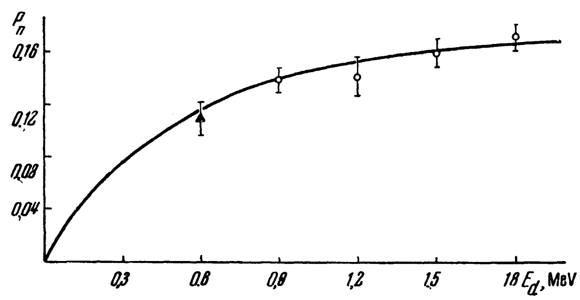

FIG. 2. Polarization of (D + D) neutrons at angle θ_n(lab) = 49° obtained from measurements with a thick target for various deuteron energies E. Δ: results of measurements by Meier, Scherrer and Trumpy[2].

TABLE 2

Ed (mev)		0.9	1.2	1.5	1.8
Pressure in counters (atm.)		1,263	1.380	1,449	1.566
Asymmetry R	0.4	1.114 ±0.013	1,114 ±0.024	1.142 ±0.018	1.148 ±0.012
	0,7	1.261 ±0.024	1.253 ±0,049	1.273 ±0.037	1,348 ±0,027

thickness 70 kev).

In spite of the difference in methods our results agree well with their data which up to the present time were the only accurate experimental data on polarization of (D + D) neutrons. Thus, the results shown in Fig. 2 increase considerably our knowledge concerning polarization of neutrons in this reaction. It follows from these results that the dependence of the polarization of (D + D) neutrons on the neutron energy is monotonic up to $E_d = 1.8$ mev. This monotonic property and the good accuracy of the values of P_{max}, as determined by us, make the (D + D) reaction a convenient source of neutrons with a colibrated polarization.

We thank the group which operates the accelerator of the Chemical Physics Institute, Academy of Sciences, USSR for their help in carrying out the experiments.

* Editor's note: That's what it says!

1 Levintov, Miller and Shamshev, J. Exptl. Theoret. Phys. (U.S.S.R.) 32, 274 (1957); Soviet Phys. JETP 5, 258 (1957).

2 Meier, Scherrer and Trumpy, Helv. Phys. Acta 27, 577 (1954).

Translated by J. L. Herson
81

Altitude Dependence of Broad Atmospheric Showers According to the Various Models of the Elementary Act of Nuclear Collisions

V. V. GUZHAVIN AND G. T. ZATSEPIN
P. N. Lebedev Physical Institute, Academy of Sciences, USSR

(Submitted to JETP editor July 20, 1956)
J. Exptl. Theoret. Phys. (U.S.S.R.) 32, 365-366 (February, 1957)

CALCULATIONS of the development in the atmosphere of nuclear-active and electron-photon components of broad atmospheric showers from primary protons of three different energies (10^{14}, 10^{16}, 10^{18} ev) were carried out for two variants of nuclear collision models. In both variants, the free path in air of the nucleons and pions was taken to be independent of the energy, and equal to 65 gm/cm^3, which corresponds to the geometric cross section of the nuclei of the atoms of the air.

In the first variant, it was assumed that for energies of the nucleons and pions higher than 5×10^{12} ev, creation of particles in nuclear collisions is described by the theory of Landau[1]. The energy spectrum and the composition of the secondary particles were assumed to be independent of whether a nucleon or a pion collided with the nucleus, and were taken from Ref. 2. The energy taken off by the secondary π-mesons was taken to be equal to 10% of the energy of the generating particle. The decay of the nuclear-active particles in the energy range $E > 5 \times 10^{12}$ ev could be neglected. In the energy region $E' < 5 \times 10^{12}$ ev, it was assumed that, independently of the nature of the generating particle of the energy E', in a collision of it with a nucleus, there is a nucleon among the secondary particles with energy $E = 0.7\,E'$, while the remaining energy $0.3\,E'$ is distributed among the created π^{+-0} mesons, the number of which is

$$n(E') = 2\,(AE'/2Mc^2)^{1/4},$$

where A is the average atomic weight of the nuclei of the air atoms, Mc^2 is the rest energy of the nucleon.

In the second variant of the calculations, in agreement with the assumption of Vernov,[3] it was taken into account that a nucleon of any energy (even for $E > 5 \times 10^{12}$ ev) loses only 30% of its energy in the formation of mesons in nuclear collisions, retaining 70%. It was further assumed that in the the collision acts only π^{+-0} mesons are produced, the multiplicity of which $n(E')$ was computed by Eq. (1), where the meson spectrum produced in the act is mono-energetic.

The development of the showers of nuclear-active particles in both variants was considered by the method of successive generation[4], with account taken of the decay of π^{+-0} mesons. The summation of the electron-photon showers arising from π^0-mesons was carried out graphically.

The results of the computations are shown in the Table where, in each column there is given the numbers obtained from the two variants (the upper is the first, the lower, the second). In the first column, we give the ratio of the energy flux $(EN_n)_p/(EN_n)_M$ carried by the nuclear-active particles for a high mountain (Pamir) to that for sea level (Moscow). The results of the calculations of the number of electrons at the altitude of Pamir N_{eP} and Moscow N_{eM} are given in the second and third columns, while the ratios of these numbers are given in the fourth. In the fifth and sixth columns, we have the computed and experimental values of the altitude dependence C_P/C_M between levels of Pamir and Moscow of the number of showers registered by usual method with the counters of corresponding area. As is evident from the Table, the experimental data on the altitude dependence of the number of showers from particles of energy $E \approx 10^{14}$-10^{16} ev agree better with the assumption on the loss of the nucleon in the nuclear collisions of only 30% of its energy. We have no experimental data on the altitude dependence of the number of showers from