



Soviet-era science, translated into English

Academy of Sciences of the USSR Reports

PHYSICS

1961

SovietRxiv

View the original and related papers at <https://sovietrxiv.org/items/ru-196101.87766>

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.

Abstract

Full Text

Academy of Sciences of the USSR Reports
1961. Volume 141, No. 6

PHYSICS

Academician of the Academy of Sciences of the Kazakh SSR Zh. S. Takibaev,
E. V. Shalagina
and G. R. Tsadikova

EMISSION OF HIGH-ENERGY α -PARTICLES IN NUCLEAR DISINTEGRATIONS BY PRO- TONS

In the study of nuclear disintegrations of the star type by cosmic-ray particles, fragments of rather high energy, of the order of several tens of electron-volts per nucleon, are recorded. Sometimes the energy of the fragments is so high that it is impossible to explain their emission by the mechanisms of nuclear evaporation or fission. Although such cases have long been observed and discussed by a number of authors ⁽¹⁾, the question has still not received a definite theoretical explanation.

In the literature there are various attempts to explain the emission of high-energy fragments. For example, in paper ⁽²⁾ this phenomenon is explained by the existence of nuclear forces with a large radius of action, which can act on aggregates of nucleons without causing their destruction. Some authors ^(3,4) relate this phenomenon to a cascade process in the nucleus, while others ⁽⁵⁾ relate it to intense local heating near the nuclear surface in the process of a nuclear cascade. V. I. Veksler ⁽⁶⁾ allowed for the appearance of high-energy fragments on the basis of the meson theory of nuclear forces; however, it is not known how this occurs. D. I. Blokhintsev ⁽⁷⁾ made a calculation according to which high-energy fragments may appear due to fluctuations of nuclear matter, reducible to collisions of the incident particle with dense clusters of nucleons inside the nucleus. The results of experiments ⁽⁸⁾ on the knocking-out of deuterons from nuclei by protons with an energy of 675 MeV can be explained by fluctuations, but the fluctuation mechanism cannot explain the emission of α -particles or heavier fragments. Therefore, the discovery of α -particles of very high energy in nuclear disintegrations is of interest.

In recent experiments ⁽⁹⁾, carried out with the proton beam of the CERN synchrophasotron, high-energy deuterons and tritons were found, but no α -particles at all were found. In stars formed by cosmic rays, high-energy α -particles were also not found ⁽⁴⁾. In paper ⁽¹⁰⁾, devoted to the study of the emission of fragments with energy greater than 60 MeV per nucleon, α -particles were recorded,

but their energy did not exceed tens of megaelectron-volts per nucleon. Therefore we carried out intensive searches for very energetic α -particles in stars formed by protons with an energy of 9 BeV in stacks of photographic emulsion.

A very simple but rather effective method was used: at first α -particles were identified from singly charged particles only by the range. Indeed, if a “black” track belongs, for example, to a proton, then it must have a length less than 0.3-0.4 cm, whereas if the same track was left by an α -particle, its length may be up to 9 cm. If, however, “gray” tracks are studied, then in the case of a proton the track must blacken within 1-1.5 cm, whereas a “gray” track left by an α -particle retains a grain density ($\geq 4g_{\min}$) over a length of 30 cm. Such a track unquestionably belongs to an α -particle, and its energy will be of the order of 1-2 BeV.

After such a preliminary search, the tracks found are analyzed in detail by various methods in order to ascertain the reliability of the particle identification. The results of the analysis of a number of very fast α -particles emitted in the process of nuclear disintegration in photographic emulsion irradiated at the

Table 1

Track No.	Kinetic energy, MeV	Angle relative to direction of primary	Dependence $g-R$	Dependence R	Dependence $g - E_k$	Width method	Constant-sagitta method	Dependence $b-R$	Type of primary star
1	1969 ± 512	$4^\circ 18' \pm 12'$	$L = 36805 \mu\text{ap}(g/g_0) \pm 4.73$	Not possible, since the track can-ondary. not	$g/g_0 = 4.73, E_k = 2200 \text{ MeV}$	ap- pli- ca- ble	Not ap- pli- ca- ble	Not ap- pli- ca- ble	$N_h = 4, n_s = 3$

Track No.	Kinetic energy, MeV	Angle relative to direction of primary	Dependence $g-R$	Type R	Dependence $g-E_k$	Width method	Constant-sagitta method $b-R$	Dependence	Type of primary star
2	615 ± 129	$17^\circ 44' \pm 12'$	g not measured	α -particle, $R = 61020 \mu$, $E_k = 595$ MeV	g not measured	α -particle	α -particle, $**$, $\overline{D} = 0.494 \pm 0.056$	α -particle	$N_h = 21$, $n_s = 7$
3	353 ± 112	$3^\circ 36' \pm 12'$	Same	α -particle, $R = 23875 \mu$, $E_k = 340$ MeV	Same	Same	α -particle, $**$, $\overline{D} = 0.472 \pm 0.094$	Same	$N_h = 10$, $n_s = 6$
4	—	$17^\circ \pm 12'$	Same	α -particle, $R = 16070 \mu$, $E_k = 275$ MeV	Same	Same	α -particle, $**$, $\overline{D} = 0.423 \pm 0.068$	Same	$N_h = 16$, $n_s = 3$
5	—	$18^\circ 36' \pm 12'$	Same	α -particle, $R = 15000 \mu$, $E_k = 265$ MeV	Same	Same	α -particle, $**$, $\overline{D} = 0.428 \pm 0.077$	Same	$N_h = 18$, $n_s = 3$
6	—	$67^\circ 03' \pm 12'$	Same	α -particle, $R = 14512 \mu$, $E_k = 255$ MeV	Same	Same	α -particle, $**$, $\overline{D} = 0.669 \pm 0.140$	Same	$N_h = 20$, $n_s = 7$
7	—	$22^\circ 42' \pm 12'$	Same	α -particle, $R = 12010 \mu$, $E_k = 230$ MeV	Same	Same	α -particle, $**$, $\overline{D} = 0.446 \pm 0.089$	Same	$N_h = 20$, $n_s = 5$

Track No.	Kinetic energy, MeV	Angle relative to direction of primary	Dependence $g-R$	Type R	Dependence $g-E_k$	Width method	Constant-sagitta method $b-R$	Dependence	Type of primary star
8	—	$31^{\circ}36' \pm 12'$	Same	α -particle, $R = 14960 \mu$, $E_k = 264$ MeV	Same	Same	α -particle **, $\overline{D} = 0.592 \pm 0.073$	Same	$N_h = 14$, $n_s = 8$
9	—	$54^{\circ}12' \pm 12'$	Same	α -particle, $R = 8690 \mu$, $E_k = 190$ MeV	Same	Same	α -particle **, $\overline{D} = 0.607 \pm 0.145$	Same	$N_h = 12$, $n_s = 12$
10	—	$21^{\circ}36' \pm 12'$	Same	α -particle, $R = 7390 \mu$, $E_k = 180$ MeV	Same	Same	α -particle **, $\overline{D} = 0.516 \pm 0.098$	Same	$N_h = 14$, $n_s = 8$
11	—	$31^{\circ}03' \pm 12'$	Same	α -particle, $R = 6600 \mu$, $E_k = 170$ MeV	Same	Same	α -particle **, $\overline{D} = 0.305 \pm 0.085$	Same	$N_h = 15$, $n_s = 5$
12	—	$24^{\circ}42' \pm 12'$	Same	α -particle, $R = 5350 \mu$, $E_k = 145$ MeV	Same	Same	α -particle **, $\overline{D} = 0.496 \pm 0.099$	Same	$N_h = 13$, $n_s = 7$
13	—	$170^{\circ}54' \pm 12'$	Same	α -particle, $R = 3890 \mu$, $E_k = 125$ MeV	Same	Same	α -particle **, $\overline{D} = 0.564 \pm 0.118$	Same	$N_h = 10$, $n_s = 1$

Fig. 1. Dependence of track width on range length. 1—protons; 2— α -particles, 3—Li; 4—Be

Figure 1: Fig. 1. Dependence of track width on range length. 1—protons; 2— α -particles, 3—Li; 4—Be

Track No.	Kinetic energy, MeV	Angle relative to direction of primary	Dependence $g-R$	Dependence E_k-R	Dependence $g-E_k$	Width method	Constant-sagitta method $b-R$	Type of primary star
14	—	$79^\circ 35' \pm 12'$	Same	α -particle, $R = 3325 \mu$, $E_k = 114 \text{ MeV}$	Same	Same	α -particle **, $\bar{D} = 0.331 \pm 0.052$	$N_h = 18, n_s = 4$

* See Fig. 1. ** See Fig. 2.

in the proton beam of the synchrophasotron of the Joint Institute for Nuclear Research in Dubna are given in Table 1. The value of the kinetic energy of the α -particle is given from measurements of its multiple Coulomb scattering. For example, for track No. 2 (energy value about 600 MeV), application of the width-measurement method for identification confirms that this track belongs to an α -particle, as is seen from Fig. 1. The constant-sagitta method (Fig. 2) also confirms that it is an α -particle. Of course, not all methods can be applied to the particle tracks found. For example, the method of measuring the track width in the region near stopping and the “sagitta” method are not applicable in the case where the track cannot be traced to its very stopping point within the photographic-emulsion stack.

Fig. 1. Dependence of track width on range length. 1—protons; 2— α -particles, 3—Li; 4—Be

Thus, the analysis shows that all 14 tracks in Table 1 belong to α -particles with kinetic energies from 100 to 2000 MeV. This thereby proves the emission of α -particles of very high energy in nuclear

Fig. 2. Histogram of the distribution of particles by the second difference \bar{D}_μ . 1— α -particles; 2—D, T; 3—protons

disintegrations produced by protons with energy 9 GeV. It should be noted, however, that some of the analyzed tracks may belong to He^3 , which is poorly separated from He^4 , i.e., from α -particles.

Fig. 2. Histogram of the distribution of particles by the second difference \overline{D}_μ .
1— α -particles; 2—D, T; 3—protons

Figure 2: Fig. 2. Histogram of the distribution of particles by the second difference \overline{D}_μ . 1— α -particles; 2—D, T; 3—protons

In conclusion we note that G. O. Treibergova and co-workers, in the same way, detected α -particles of very high energy emitted from stars produced by π -mesons with energy 7 GeV.

The authors express their gratitude to Acad. V. I. Veksler and to the staff of the Joint Institute for Nuclear Research for their assistance and help in the irradiation.

Kazakh State University
named after S. M. Kirov

Received
14 VIII 1961

REFERENCES

1. U. Camerini, W. Lock, D. Perkins, *Cosmic Ray Physics*, 1, IL, 1954, p. 51.
2. D. H. Perkins, Proc. Roy. Soc., **A 203**, 399 (1950).
3. S. Nakagawa, J. Phys. Soc., **12**, 747 (1957).
4. O. C. Sørensen, Phil. Mag., **42**, 188 (1951).
5. S. Nakagawa, Nuovo Cimento, **9**, 780 (1958).
6. V. I. Veksler, DAN, **77**, No. 6, 865 (1952).
7. D. I. Blokhintsev, ZhETF, **33**, 1295 (1957).
8. L. Azhgirei, I. Vzorov et al., ZhETF, **33**, 1185 (1957).
9. V. T. Cocconi, T. Fazzini et al., Phys. Rev. Letters, **5**, No. 1, 19 (1960).
10. N. N. Lazarev, T. P. Lazareva, Zh. S. Takibaev, Tr. Inst. Nucl. Phys. Acad. Sci. KazSSR, **5** (1961).

Note: Figure translations are in progress. See original paper for figures.

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.