Spectrum of DT neutrons from a plasma focus

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The spectrum of DT neutrons from a plasma focus has been studied at angles of 0°, 90°, and 180° from the axis of the discharge chamber. The results do not support the interpretation that the DT neutrons in the plasma focus are produced by a fusion mechanism.

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All the conclusions which have been reached regarding the mechanism for neutron production in a plasma focus have been based on the anisotropy of the emission and the spectrum of the DD neutrons from the reaction D(d,n) ^{3}He (Refs. 1–5). In this letter we report a study of the spectrum of DD neutrons produced in a plasma focus with a discharge chamber filled with an equal-parts mixture of deuterium and tritium, $D_{0.5}T_{0.5}$. No previous measurements of the spectrum of DT neutrons from a plasma focus by the time-of-flight method have been reported, apparently because of the difficulties presented by such measurements.

In this letter we report a study of the spectrum of DT neutrons produced in a plasma focus in a discharge chamber with approximately the Filippov configuration. When a capacitor bank that can hold an energy up to 60 kJ is discharged into this chamber, filled with a deuterium-tritium mixture at a pressure between 18 and 23 Torr, with an initial voltage from 18.5 to 21 kV, the integrated neutron emission is $N_0 \cong 10^{11}$ neutrons per pulse of length $\tau_{0.5} \cong 20$ ns. The DT neutron spectrum is measured by a time-of-flight method simultaneously along three directions with respect to the chamber axis: 0° (this is the direction from the anode toward the cathode), 90°, and 180°. The measurement is shown in Fig. 1.

The neutron detectors (1,2,3) are all placed at a distance $R = 98$ m from the plasma focus (4). Each detector consists of a multisection plastic scintillator (polystyrene with 2% p-terphenyl and 0.02% POPOP), 36 cm in diameter and 12.5 cm thick, a conical plastic lightguide, and an SNFT-8 fast high-current photomultiplier.[6] The resolving time of the detector is $t_{0.5} \cong 8$ ns. The time distribution of the DT neutrons is measured at a point 3.4 m from the plasma focus by a detector (5) to determine the effect of the source operating time.[7] At this close range, the distribution is essentially undistorted by the energy spurt of the neutrons. The resolving time of this detector was chosen the same as for detectors 1, 2, and 3. The electrical output signals from detectors 1, 2, 3, and 5 were fed along cables of precisely equal length to oscilloscopes (6, 7, 8, 9). The integrated neutron emission was monitored by a silver-activation method. The scattered-neutron background was reduced by shielding (10) around the chamber. Detector 5 was enclosed in a lead box (11) to reduce the background of scattered x rays.

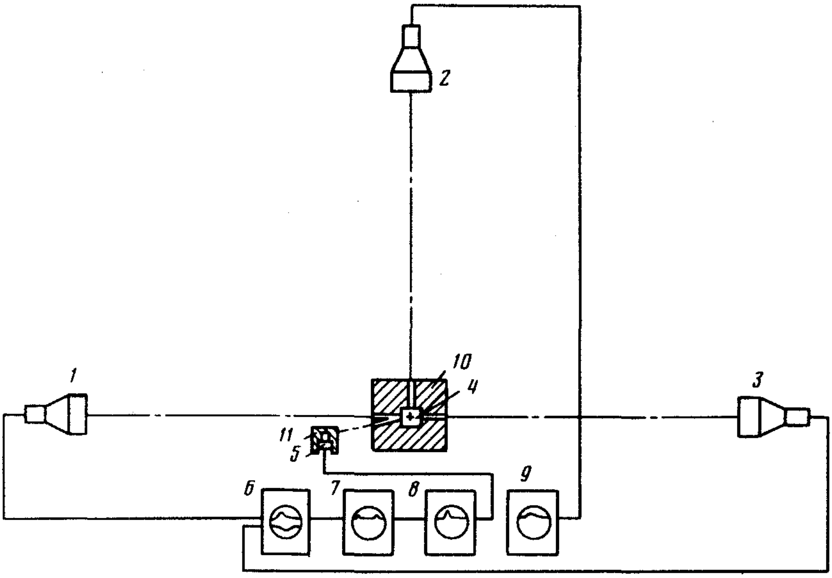

FIG. 1. The measurement arrangement. 1, 2, 3—Detectors; 4—plasma focus; 5—detector; 6–9—oscilloscopes; 10—shielding; 11—lead box.

The background measurements showed that the emission from the plasma focus was very effectively collimated in all three directions and that there were essentially no scattered neutrons in these measurements.

To find the time distributions $u(t)$ of the DT neutrons undistorted by the source operating time and by the resolving time of the detectors, we used the equation

$$F(t)=\int_0^t u(\tau)g(t-\tau)\,d\tau,$$

where $F(t)$ is the time distribution measured in one direction, and $g(t)$ is the response of the detection system to the time distribution of the neutrons undistorted by the spectrum.

Figure 2 shows some typical oscilloscope traces of the pulses of the time distributions $F(t)$ and $g(t)$ recorded for one discharge. Figure 3a shows the DT neutron spectrum for this discharge. The energy resolution is $\Delta E/E = 0.4\%$ at the 0.5 level of the spectral distributions; this resolution is apparently determined by the errors that arise during the reconstruction of the original shape of the time distributions $U(t)$. In the study of the DT neutron spectrum we analyzed ~ 30 discharges corresponding to identical chamber operating conditions. Figure 3(b) shows the range over which the spectra varied from discharge to discharge.

From the analysis of the measurements of the DT neutron spectrum we can draw some conclusions:

1) The shifts of the spectra in the directions 0° ($E_{max} = 14.7 \pm 0.1$ MeV) and 180° ($E_{max} = 13.56 \pm 0.10$ MeV) and the shape of the spectra indicate that the centers of

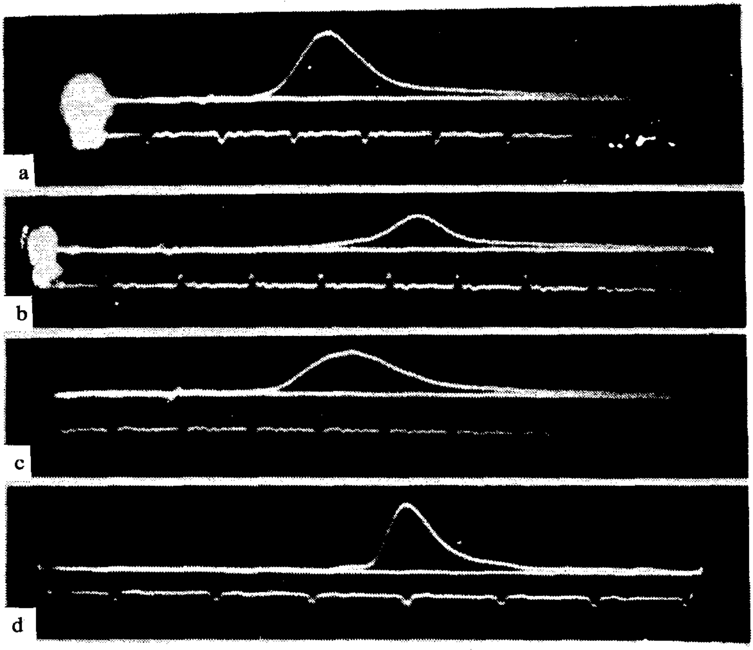

FIG. 2. Oscilloscope traces of the time distributions of the DT neutrons (the period of the time marker is $T = 40$ ns). a—In the direction 0°; b—180°; c—90°; d—at a distance $r = 3.4$ m.

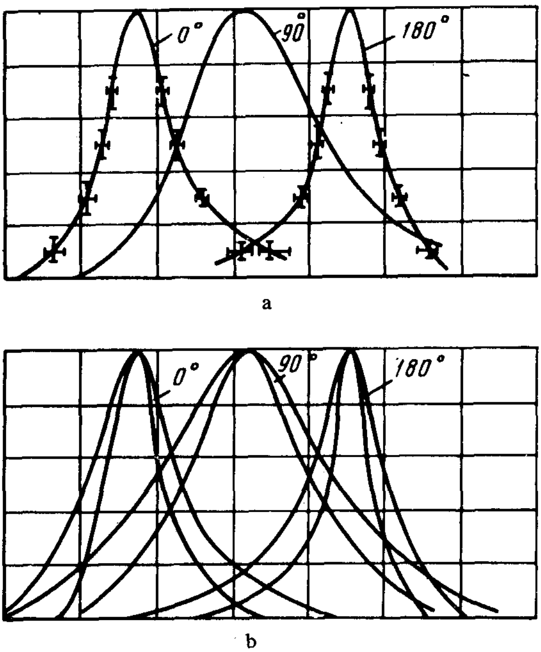

FIG. 3. Spectra of the DT neutrons. a—For the time distributions in Fig. 2; b—range over which the spectra vary from discharge to discharge.

mass of the interacting particles are moving at velocities up to $V \cong (1-2) \times 10^8$ cm/s in the direction from the anode toward the cathode.

2) The spectral broadening in the 90° direction is caused by a radial velocity component $V_r \cong 7 \times 10^7$ cm/s.

3) In the case of a fusion mechanism for the neutron production, the temperature of the fusion reaction, determined from the spectral shape, would vary from discharge to discharge within the range $1.1 < \Theta < 3.7$ keV.

The number of DT neutrons emitted in the discharges for which the spectra were analyzed varied by no more than 30% from one discharge to another, having the value $\overline{N}_0 = (1 \pm 0.3) \times 10^{11}$ over the emission time $\tau_{0.5} \cong 20$ ns.

In some corresponding experiments with a bubble chamber, Trusillo *et al.*[8] measured the size of the neutron production region, finding $h \cong 8-12$ mm and a diameter of 2–4 mm.

In an effort to interpret the experimental results, we calculated the spectra of DT neutrons from a model of a moving fusion reactor with constant and varying velocities and also for an accelerator mechanism for the neutron production, working by analogy with the calculations by Bernstein.[3]

Comparing the calculated and experimental results, and appealing to the measurements of the size of the neutron production region,[8] the neutron emission, and the source operating time, we do not find evidence favoring a fusion mechanism for the production of DT neutrons in the plasma focus.

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