of the mass 14 triad using only central and spin-orbit interactions, without invoking any tensor force.

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NEUTRONS OF POSSIBLE THERMONUCLEAR ORIGIN*

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Published accounts of experiments designed to achieve plasma temperatures of thermonuclear interest have so far made use of the pinch effect. We have succeeded in producing neutrons from a deuterium plasma compressed by a rising axial magnetic field.

Our device, named Scylla, at present employs three single-turn coils having the configuration shown in Fig. 1. The coils, suitably insulated, surround a cylindrical ceramic tube

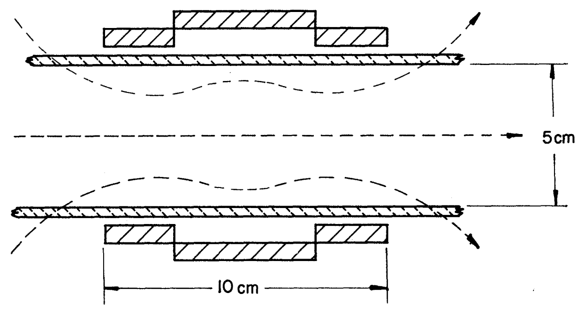

FIG. 1. Section through coils and ceramic tube, with typical magnetic field lines suggested by the broken lines. The set of coils in subsequent designs have been made from a single piece of brass with a common outer radius for the middle and end portions.

through which low-pressure deuterium gas slowly flows. The coils are connected in parallel to a short parallel-plate transmission line leading to an oil-immersed junction connecting with eighty 10-ft lengths of RG-14/U coaxial cable. These cables in groups of eight lead to ten four-element triggered spark gaps[1] each mounted on a low-inductance 0.88-μf capacitor of 100-kv rating.[2] The inductance of the coils is 0.034 μh and of the source 0.038 μh, so that 47% of the capacitor voltage appears initially across the coil terminals.

With the capacitors charged to 70 kv and with no gas present, a circumferential electric field of 1.6 kv/cm exists initially at the tube wall near each end coil. One quarter period (1.25 μsec) later this field has decreased to zero and the central axial magnetic field has risen to about 58 kilogauss.

With gas present, the initial electric field, aided by rf pre-excitation, promptly breaks down the gas and the resulting plasma current sheath is repelled by the current in the coils. The strong shock waves initiated by this mechanism[3] pass through the central region in about 0.1 μsec, ionizing the gas there, and heating the plasma. During the first compression cycle the gas is further heated by reversible adiabatic compression by the rising axial magnetic field and by irreversible joule heating. In Scylla the temperature reached at the first peak compression appears insufficient for the D-D reaction to occur.

The escape of particles during the first and subsequent compressions is reduced because of the mirror properties of the axial magnetic field used.[4] Evidently scattering out of mirror confinement into the mirror loss solid angle is heavily weighted toward the early low-temperature stage of the compression (assuming no residual neutral molecules remain), for it depends on multiple Rutherford scattering proportional to $1/W^2$, where $\underline{W}$ is the particle energy. Hence the degree of confinement is very much dependent on the temperature assumed for initial shock preheating. In planning the experiment, the magnetic field rise rate was chosen to give negligible loss for a starting temperature of 10 ev and a starting density of 10 microns. The confinement in practice is undoubtedly greater than that indicated by the low average mirror ratio (ca 1.4) of the field, for during compression the magnetic field fails to penetrate the highly conductive plasma in the short time involved.

We have observed the emission of both x-rays and neutrons from Scylla in bursts during the second and to a lesser extent later compressions. X-rays, when observed, occur during the beginning and the end of a compression cycle when the electric field is high. In contrast, neutrons occur only in symmetrical bursts lasting about 1 μsec centered on the instant of peak compression. Many of the x-rays, with a maximum energy of at least 200 kev, appear to originate at the tube walls about 13 cm from the midplane where a Pyrex tube used in earlier experiments was darkened as if by electron bombardment. Energetic x-rays occur only at relatively low gas pressures (below 50 microns), in contrast to neutrons which occur over a broad pressure range. The absence of rf pre-excitation greatly enhances x-ray yield and suppresses neutron yield. Impurities appear to have the same effect.

Fig. 2 shows the pressure dependence of neutron yield with the capacitors charged to 70 kv. Ten to twenty observations were made at each pressure and a considerable variation in yield was noted, with the yield usually increasing after several firings at about two-minute intervals. We attribute much of this variation to a cleaning-up process in the discharge tube. The five highest yields at each pressure have been indicated. The neutron yield was measured with a silver counter that had been calibrated using D-D neutrons from a Cockcroft-Walton accelerator.

X-rays present only at low pressures appear to arise from electrons accelerated in orbits

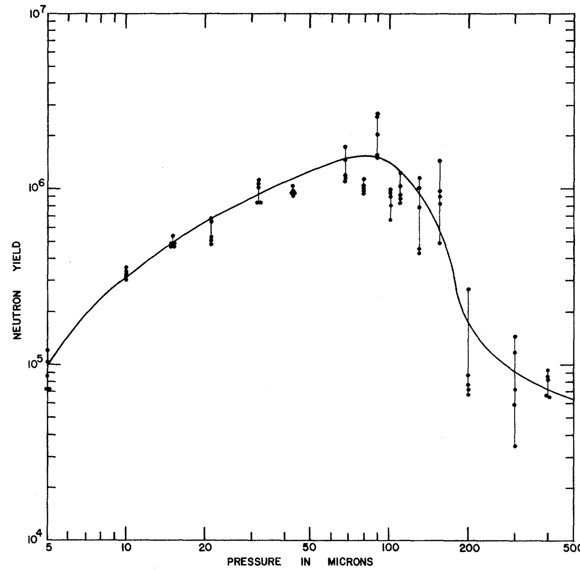

FIG. 2. Neutron yield as a function of initial deuterium pressure with capacitor bank charged to 70 kv.

described by a single-particle model,[5] and then scattered out of mirror confinement. At higher pressures, collisions interfere with this runaway process and a cooperative model must be employed. Although at low pressures some runaway deuterons may account for part of the neutron yield, it appears likely from the contrasting behavior of x-rays and neutrons with regard to time of occurrence, pressure, rf pre-excitation and impurities that the majority of the neutrons arise from D-D collisions in the plasma which must be considered as having undergone an adiabatic compression by the rising axial magnetic field. Additional evidence supporting this view comes from earlier experiments in which the center coil was absent and the two end coils were supplied with current from independently timed capacitor banks. A small discrepancy in timing drastically reduced the neutron yield, showing that plasma containment is of utmost importance. The absence of neutrons during the first compression cycle suggests that the irreversible plasma heating during this cycle is needed to raise the starting temperature to a value such that a subsequent compression results in neutron production.

The authors are greatly indebted to Keith Boyer for suggesting the experiment and to James L. Tuck for formulating the rate requirements. They are also indebted to Thomas M. Putnam and Hugh K. Jennings for aid in the de-

sign and construction of the various power supplies and control circuits.

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The term mirror refers to the reflection and, with suitable geometry, axial confinement of moving charged particles by their reflection from a region of increasing axial magnetic field as a result of conservation of canonical angular momentum and energy. The loss solid angle for particles moving in helical paths along magnetic lines is found to be $2\pi\,[1 - (1 - 1/R)^{\frac{1}{2}}]$ where the mirror ratio R is the ratio of field intensity at the mirror to that within the region of confinement. The basic equations underlying mirror reflection are given by R. F. Post, Revs. Modern Phys. 28, 338, (1956).

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CIRCULAR POLARIZATION OF A^{37} INTERNAL BREMSTRAHLUNG *

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The current situation in beta decay is that it seems extremely likely that the beta interaction may be described in terms of a two-component theory, with lepton conservation, and with all coupling constants except(C_V, C_V') and (C_A, C_A') equal to zero. This situation must have the consequence that the internal brehmstrahlung (IB) accompanying K capture should be almost totally and right circularly[1] polarized (assuming left-handed helicity for the neutrino) at all energies substantially above the characteristic x-ray energies.[2,3] This can be easily seen from the formula[4] for this polarization:

$$P_{1S}(k)=p_{1S}(k)\;\frac{[\sum_f |\langle 1\rangle_{fi}|^2](|C_V|^2-|C_S|^2)+[\sum_f|\langle\sigma\rangle_{fi}|^2](|C_A|^2-|C_T|^2)}{[\sum_f |\langle 1\rangle_{fi}|^2](|C_V|^2+|C_S|^2)+[\sum_f|\langle\sigma\rangle_{fi}|^2](|C_A|^2+|C_T|^2)},$$

where P_{1S} (k) is a function of photon energy within ~1% of unity for all energies of interest here. The meaning of all other symbols is standard and may be found in reference 2 explicitly.

It is easy to verify that the formula for IB polarization is essentially the same[5] as for the polarization of electrons emitted in beta decay, and so one may (for all practical purposes) equate the two kinds of experiments and regard them as of a single type. The prediction for this type of experiment is virtually 100% polarization whether or not the transition is mixed (both Fermi and Gamow-Teller matrix elements nonzero). But the result is sensitive to the possibility $|C_T|^2/|C_A|^2 \neq 0$. Recently the IB polarization of Ge^{71} was measured by Bernardini and coworkers[6], who found an effect of only 40% of full polarization. Our present result for A^{37} indicates full positive polarization to within 15%, confirming the surmise[6] that the Ge^{71} result was very likely affected by source impurities and multiple scattering, and supporting the full validity of the two-component theory.

The technique used here was basically the same as that introduced by Schopper[7] and Boehm and Wapstra[8]. The IB photons were scattered off the inner surface of a 3 in. i.d. by 8 in. long Armco iron cylinder, and detected in a $1\frac{3}{4}$ in.×2 in. NaI(Tl) crystal. A lead plug centered in the iron cylinder prevented the direct trans-