reactor at Kahl and the KRB reactor at Gundremmingen in West Germany. But the contract only covers the amounts of fuel which cannot be handled by a German re-processing plant being built at Karlsruhe. Eurochemic will have to console itself with the thought that if member countries do not use its facilities fully, they will find themselves paying for its deficits. Already the OECD council has agreed that up to \$5.3 million should be made available for 1968 and 1969 to cover expenses not covered by receipts.

ENEA also supports a variety of smaller projects. The computer programme library at Ispra in Italy, originally set up for a three year period, is now to continue indefinitely. The library receives computer programmes from member countries, checks them, and then sends them out to interested organizations. Because the checking process normally costs about \$1,000 for each programme—and every programme needs correction—the library is a way of avoiding costly duplication in the member countries. Another centre, the Neutron Data Compilation Centre at Saclay, contains a library of neutron data; and the Seibersdorf Project, near Vienna, is a way of gaining experience of the possibilities of food preservation by irradiation. The agency has also been involved in the problems of the disposal of radioactive waste. The latest annual report of the agency gives details of the first dumping of radioactive waste it has organized. Five countries—Britain, France, West Germany, Belgium and the Netherlands—agreed to take part in the experi-

mental programme, and 11,000 tons of packaged waste was collected together, securely packaged and dumped at a depth of 16,400 ft. in the eastern Atlantic.

In addition to this, the agency organizes a number of joint committees, covering such subjects as reactor safety, reactor physics, magneto-hydrodynamic power generation and nuclear data. Increasingly, it seems that the agency is moving away from large projects, principally because these are no longer wanted by member countries. Since nuclear power became a commercial activity, collaboration has seemed less and less attractive. But there is now a suggestion in the air for a large scale project in the fast reactor field, and a meeting of ENEA's top scientific committee, with representatives from all member countries, will be discussing the proposal next month. If enough of the countries are interested, the proposal could become a reality, but in the present climate this is unlikely. The United Kingdom, which has already been responsible for shelving one ENEA proposal, for a ultra-high flux research reactor, is unlikely to feel that this is the time for undertaking new expenditure abroad, particularly in a field in which the UKAEA has already made substantial investment at home. The UK would have little to gain and a great deal to give away in a project of this sort. And Euratom is too busy deciding (more accurately, failing to decide) its own research programme to take any interest. It rather looks as if ENEA will have to content itself with more modest projects for the next few years.

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Is the Special Theory Right or Wrong?

In *Nature* for October 14, 1967, Professor H. Dingle argued that the special theory of relativity is incorrect, and Professor W. H. McCrea put an opposing view. Some correspondence on the same subject has already appeared. What follows is a further selection from the correspondence on this subject.

Experimental Verifications of the Theory of Relativity

As a postscript to the articles by Professor H. Dingle¹ and by Professor W. H. McCrea², we should like to draw attention to two recent experiments which bear directly on items which Dingle has felt obliged to doubt, but which have been mentioned in "News and Views"³—the relativity of time as exemplified, in particular, by the "clock paradox" (ref. 4) and the second postulate of the theory of relativity, which asserts that the velocity of light is independent of the motion of the source⁵. The apparent slowing down of moving clocks, long ago verified for straight-line motion⁶, has now been established for a circular trajectory as well, a time-dilation factor of 12 being verified to within 2 per cent. In another experiment, bursts of γ -rays emitted from fast moving mesons have been timed as they cross the laboratory; the velocity obtained is equal to the standard value for the velocity of light c to within 1.3 parts in 10^4 even though the source velocity is itself very close to c .

The result on time-dilation is obtained as a by-product of another investigation. In the muon storage ring⁷ at CERN, muons of momentum 1.274 GeV/c are injected into a circular orbit in an almost uniform magnetic field.

The design includes vertical and horizontal magnetic focusing to prevent loss of particles. The circulating muons can be detected by means of the decay, $\mu^- \rightarrow e^- + \nu_\mu + \bar{\nu}_e$ for the electron produced, which has less momentum than the parent μ^- , is bent more sharply in the magnetic field and emerges towards the centre of the ring. Some of these electrons are detected by counters, the number observed at any time being proportional to the number of muons left in the ring at this time. The lifetime of muons at rest is $\tau_0 = (2.200 \pm 0.0015) \mu\text{sec}$ (ref. 8), and special relativity then predicts for the muon in flight, the dilated lifetime $\tau = \tau_0 (1 - v^2/c^2)^{-1/2} = 26.72 \mu\text{sec}$. Here it is assumed that no special correction is necessary when the orbit is deflected by a magnetic field, and that the decay rate of the particle in its rest system is not altered by the acceleration experienced. The observations⁷ (see Fig. 1) show an exponential decay with lifetime $26.15 \pm 0.03 \mu\text{sec}$, agreeing with the theory to about 2 per cent. (The marginally shorter lifetime is ascribed at present to a slow loss of muons, perhaps as a result of imperfections in the magnetic field.) This result removes any lingering suspicion that some unus-

Fig. 1. Decay electron counting rate from stored muons (log-scale) plotted against time. Fitted lifetime $\tau = 26.15 \pm 0.03 \mu\text{sec}$. The small oscillations are due to the precession of the muon spin (see ref. 4).

pected effect associated with acceleration would compensate the time-dilation in a circular or out-and-return journey; the "clock-paradox" is established as an experimental fact associated with the time-keeping of radioactive material in direct comparison with standard laboratory scales of time.

The possible influence of source velocity on the velocity of propagation of γ -rays has also been studied at CERN. When 19 GeV protons hit a beryllium target in the proton synchrotron, the resulting forward-emitted γ -rays have a sharp pulse structure in time as a result of the bunching of the protons in the accelerator by the applied radio frequency. By measuring the time of arrival of the γ -ray bunches ($E_\gamma > 6 \text{ GeV}$) at two points along the beam, and comparing in each case with the radio-frequency phase, the velocity is obtained as a simple product of a laboratory distance (31.4503 metres) and the radio frequency applied to the synchrotron (9.53220 MHz). Including small corrections, the result is $(2.9979 \pm 0.0004) \times 10^{10} \text{ cm/sec}^{-1}$ (ref. 9), agreeing with the standard velocity of light c to 1.3 parts in 10^4 .

In such a high-energy collision, the velocity of the centre of mass is a substantial fraction of c , so it can hardly be doubted that the γ -rays come from a moving source. That the γ -ray spectrum observed in such collisions is dominated by the production of π^0 mesons¹⁰ (followed by $\pi^0 \rightarrow 2\gamma$ giving in the π^0 rest frame two γ -rays of 70 MeV) was established first for cosmic ray events¹¹ and later in the laboratory¹². Both the γ -ray intensity and the spectral shape are explained by this hypothesis, admittedly with the use of the relativistic formula for the Doppler shift. In the present experiment, γ -rays with $E_\gamma > 6 \text{ GeV}$ are selected, and the corresponding π^0 must have (according to relativity) $V_{\pi^0} > 0.99975 c$. It is concluded that the second postulate is verified accurately even for very high source velocities.

The Michelson-Morley experiment has shown that the velocity of light is not changed by the motion of source and detector together. Combining with the above result, one may conclude that neither the motion of the source nor the motion of the detector influences the velocity.

The earlier double star observations and other experiments are discussed in ref. 6, including difficulties in interpretation raised by the extinction theorem.

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¹ Dingle, H., *Nature*, **216**, 119 (1967).

² McCrea, W. H., *Nature*, **216**, 122 (1967).

³ *Nature*, **216**, 113 (1967).

⁴ See, for example, Dingle, H., *Proc. Phys. Soc. (London)*, **A**, **69**, 925 (1956); *Nature*, **180**, 1275 (1957).

⁵ Dingle, H., *Nature*, **188**, 1761 (1959); *Mon. Not. Roy. Astro. Soc.*, **119**, 67 (1959).

⁶ Rossi, B., Hilberry, N., and Hoag, J., *Phys. Rev.*, **57**, 461 (1940). Rasetti, F., *Phys. Rev.*, **60**, 198 (1941).

⁷ Farley, F. J. M., Bailey, J., Brown, R. C. A., Giesch, M., Jostlein, H., van der Meer, S., Picasso, E., and Tannenbaum, M., *Nuovo Cimento*, **44**, 281 (1966). Bailey, J., Bartl, W., Brown, R. C. A., Farley, F. J. M., Jostlein, H., van der Meer, S., and Picasso, E., *Proc. Intern. Symp. on Electron and Photon Interactions at High Energies, Stanford* (1967).

⁸ Feinberg, G., and Lederman, L. M., *Ann. Rev. Nucl. Sci.*, **13**, 466 (1963).

⁹ Alväger, T., Farley, F. J. M., Kjellman, J., and Wallin, I., *Phys. Lett.*, **12**, 280 (1964). Alväger, T., Bailey, J. M., Farley, F. J. M., Kjellman, J., and Wallin, I., *Arkiv Fysik*, **31**, 145 (1966).

¹⁰ Bjorklund, R., Crandall, W. E., Moyer, B. J., and York, H. F., *Phys. Rev.*, **77**, 213 (1950). Steinberger, J., Panofsky, W. K. H., and Steller, J., *Phys. Rev.*, **78**, 802 (1950).

¹¹ Carlson, A. G., Hooper, J. E., and King, D. T., *Phil. Mag.*, **41**, 701 (1950).

¹² Fidecaro, M., Finocchiaro, G., Gatti, G., Giacomelli, G., Middlekoop, W. C., and Yamagata, T., *Nuovo Cimento*, **24**, 73 (1962).