our figures suggest that a large proportion of the observed flux is not a true primary flux of light nuclei but secondary in origin.

An experiment is now in progress to test the above assumptions by observing the proportion of lithium, beryllium, and boron fragments produced by interactions of primary nuclei occurring in the plastic (cellulose acetate) layers of a stripped emulsion-plastic stack.

We wish to thank Mrs. B. Wargotz for her assistance in scanning.

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[1] Characterized by a recoil proton at a much greater angle than the fast fragments of the incident nucleus. Charge balance can be obtained. The proportion of hydrogen interactions observed is in agreement with that calculated from the known composition of emulsion.

[2] H. Bradt and B. Peters, Phys. Rev. **80**, 943 (1950).
[3] Dainton, Fowler, and Kent, Phil. Mag. **43**, 729 (1952).
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Total Ionization of α Particles of Po in Mixtures of Gases

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THE total ionization of α particles of Po has been measured in the following mixtures of gases: $A-N_2$, $A-H_2$, $A-CH_4$, $A-C_2H_5OH$, $A-C_6H_6$.

The experimental apparatus consisted of a gridded ionization chamber attached to a gas purifier. The purification of argon, nitrogen, and methane was done with continuous circulation of the gases over Ca–Mg turnings kept at 300–400°C. The hydrogen was circulated over Mg only. In the mixtures of argon with C_2H_5OH and C_6H_6 the previously purified argon was added to the other gas which had a purity higher than 99.9 percent. The pressure in the chamber was such that the α particles lost all of their energy in the sensitive volume and a field was produced that assured the complete collection of the electrons. The amplification chain consisted of a preamplifier and a Bell and Jordan amplifier[1] or a Model-100 amplifier.[2] The pulses were analyzed with an amplitude discriminator.

The results of our measurements are shown in Figs. 1 and 2. The ratio W_A/W_m between the average energy expended in producing an ion pair in argon and that in the mixture is plotted as a function of the parameter $z=s_1p_1/(s_1p_1+s_2p_2)$, where s_1 and s_2 are the stopping powers of the two components and p_1 and p_2 their pressures. It can be shown that the ionization in the mixtures is a linear function of z if it is assumed there is no interaction between the components of the mixture itself.[3] It is seen in Figs. 1 and 2 that the ionization rises rapidly with z and reaches a maximum at percentages of about 2 percent, 0.2 percent, and 0.2 percent for CH_4, C_2H_5OH, and C_6H_6, respectively. The ionization exceeds that in pure argon by 1.5 percent, 15 percent, and 21 percent respectively. These results can be interpreted by assuming that the

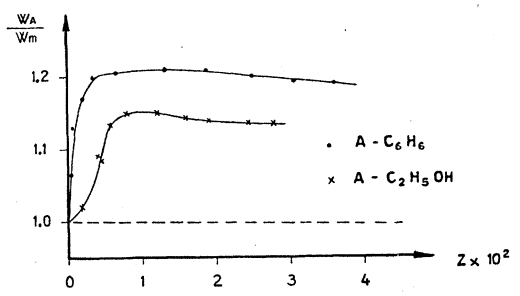

FIG. 1. Variation of W_A/W_m with z. The dotted line shows the variation of ionization in the mixture on the assumption of independent ionization of the components. The stopping powers used are: $s(A)=0.95$, $s(C_6H_6)=3.33$, $s(C_2H_5OH)=2.02$.

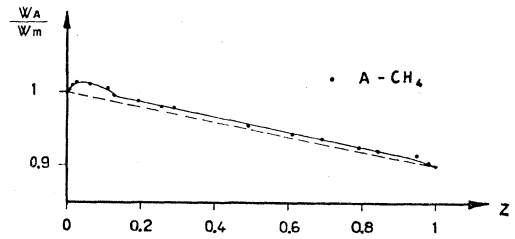

FIG. 2. Variation of W_A/W_m with z. The dotted line shows the variation of ionization in the mixture on the assumption of independent ionization of the components. The stopping powers used are: $s(A)=0.95$, $s(CH_4)=0.91$.

excited atoms of argon transfer their energy, during a collision, to atoms of foreign gas and ionize them: $A+S\rightarrow S^+ + A + e$, where S indicates a molecule of foreign gas (CH_4 or C_2H_5OH or C_6H_6). This process is possible because the ionization potentials of foreign gas are lower than that of argon. A, CH_4, C_2H_5OH, and C_6H_6 have ionization potentials of 15.4, 14.5, 11.5, and 9.6 volts, respectively, and it can be seen that the lower the potential of the foreign gas, the higher is the maximum ionization of the mixture.

It can further be noted that at the conditions of pressure and temperature in which the mixture was studied, the time of collision of an excited atom of argon with one of foreign gas is $\sim 5\times 10^{-11}$ sec, considering that an excited atom has a collision cross section ten times the geometrical cross section.[4]

The curves of W_A/W_m for $A-H_2$ and $A-N_2$ mixtures are in agreement with the measurements of Haeberli, Huber, and Baldinger,[3] and Valentine and Curran.[5] In these mixtures the ionization values can be understood when the ionization of δ rays is taken into account.[3]

A more detailed description of the results is to be published in *Il Nuovo cimento*.

[1] W. H. Jordan and P. R. Bell, Rev. Sci. Instr. **18**, 703 (1947).
[2] W. C. Elmore and M. Sands, *Electronic Experimental Techniques* (McGraw-Hill Book Company, Inc., New York, 1949), p. 165.
[3] Haeberli, Huber, and Baldinger, Helv. Phys. Acta **23**, 481 (1950); **26**, 145 (1953).
[4] J. P. Molnar, Phys. Rev. **83**, 940 (1951).
[5] M. Valentine and S. C. Curran, Phil. Mag. **43**, 964 (1952).

Decay-Electron Spectrum of the μ Meson*

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(Received October 14, 1953)

WE have completed an experiment to determine the shape of the energy spectrum of electrons from the decay of the μ meson. Pi mesons from a paraffin target in the gamma-ray beam of the M.I.T. synchrotron passed through an argon-filled cloud chamber, at one wall of which was an anthracene scintillation counter (see Fig. 1). The magnetic field in the cloud chamber (9000 gauss) selected a broad momentum band of positive pions which crossed the chamber and stopped in the anthracene crystal or the Lucite light-pipe behind it. The positron from the subsequent $\pi-\mu-e$ decay was then visible if it came out in a favorable direction.

Out of 4350 pictures, 830 showed clearly-associated meson and electron tracks. Rigorous selection criteria were necessary to avoid biasing the sample. The lower limit of acceptable initial kinetic energy was set at 20 Mev. Each event was reconstructed graphically and required to pass the following tests: (a) the calculated electron trajectory in the Lucite must intersect the known end point within stated limits; (b) any electron of energy between 20 Mev and 52.4 Mev having the initial direction determined from this trajectory must have a path in the Lucite plus anthracene of less than 4.2 cm; (c) any electron with this initial direction and with energy between 20 Mev and 52.4 Mev must have a visible track in the cloud chamber of more than 5 cm of arc. Consideration

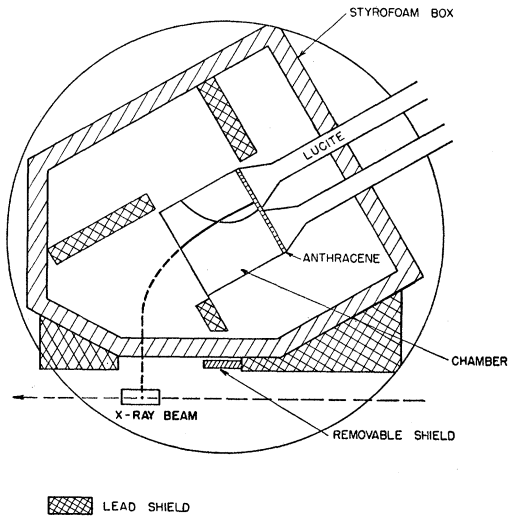

FIG. 1. Schematic plan view of the cloud chamber and scintillation counter—the large circle is the outer edge of the magnet coil.

of a number of possible effects has convinced us that there is no appreciable bias in the sample thus obtained. Of the 830 tracks, 280 satisfied these criteria.

The momentum of each track was obtained from coordinate measurements on the photographic film, plus geometric measurements on the reprojected image, taking into account the corrections for conical projection, gas motion during expansion, radial component of the magnetic field, and variation of the field along the track. The initial energy was then obtained by adding to the observed energy the collision loss of the electron in the Lucite and anthracene.

We compare our results with the energy spectrum which has been calculated from the direct-interaction theory of the decay of a muon into an electron and two neutrinos.[1] The spectrum, neglecting some small terms, may be written

$$P(E)dE=\frac{4E^2}{W^4}\left[3(W-E)+2\rho\left(\frac{4}{3}E-W\right)\right]dE,$$

where W is the maximum possible electron energy and ρ is a parameter which could have any value from 0 to 1 depending on the nature of the interaction assumed. To take account of the radiation loss of electrons in the Lucite plus anthracene (the mean path length was 0.069 radiation length), we have integrated over this spectrum with a radiation-loss distribution function.[2] This "smeared-out" set of spectra should then be directly comparable with the experimental spectrum, and indeed a good fit proves to be possible.

The value of ρ and the corresponding standard error (which includes the uncertainties in W and in individual momentum estimates) are found by the method of maximum likelihood.[3] Using the new value of the muon mass,[4] $m_\mu=207.0\pm0.6m_e$, we find $\rho=0.50\pm0.12$; that is, the spectrum does not go to zero at the end point. This agrees with Bramson, Seifert, and Havens,[5] whose result, when corrected for m_μ, is 0.48 ± 0.13.

Previous results,[6–8] when corrected for the new meson mass (and, in references 6 and 7, for radiation loss) appear to be consistent, within their statistical and estimated errors, with the value reported here.

* Supported in part by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
† Now at Ecole Nationale Supérieure des Télécommunications, Paris, France.
[1] Tiomno, Wheeler, and Rau, Revs. Modern Phys. **21**, 144 (1949); L. Michel, Proc. Phys. Soc. **A63**, 514 (1950).
[2] L. Eyges, Phys. Rev. **76**, 264 (1949).
[3] H. Cramèr, *Mathematical Methods of Statistics* (Princeton University Press, Princeton, 1951), p. 498. We have also computed ρ from the first four moments of the experimental distribution, and we find $\rho=0.49$, 0.47, 0.51, 0.52. The agreement of these results among themselves indicates that our sample is consistent with the assumed shape of the theoretical curve.
[4] Smith, Birnbaum, and Barkas, Phys. Rev. **91**, 765 (1953); G. Ascoli, Phys. Rev. **90**, 1079 (1953); Lederman, Booth, Byfield, and Kessler, Phys. Rev. **83**, 685 (1951). The latter measurement depended on the pion mass, and therefore now agrees with the former two.
[5] Bramson, Seifert, and Havens, Phys. Rev. **88**, 304 (1952).
[6] A. Lagarrigue and C. Peyrou, J. phys. **12**, 848 (1951); A. Lagarrigue, Compt. rend. **234**, 2060 (1952).
[7] Sagane, Gardner, and Hubbard, Phys. Rev. **82**, 557 (1951).
[8] H. W. Hubbard, thesis, University of California, 1952 (unpublished).

Errata

Unusual $\pi-\mu$ Decays in Photographic Emulsions, W. F. FRY [Phys. Rev. **86**, 418 (1952); **91**, 130 (1953)]. Because of an oversight, a reference to the work of Ioffe and Rudick[1] concerning the γ-ray emission from $\pi-\mu$ decays was not included in these publications. The results of the calculations of Ioffe and Rudick are in general agreement with the experimental observations.

[1] B. Ioffe and A. Rudick, Doklady Akad. Nauk. S.S.S.R. **82**, No. 3, 359 (1952).

Scintillation Study of As^{77} and Br^{77}, M. E. BUNKER, R. J. PRESTWOOD, AND J. W. STARNER [Phys. Rev. **91**, 1021 (1953)]. The third line in the second column on page 1021 should read " . . . a discriminator potential of 6 volts (~26 kev) is much too broad. . . ." The numeral 6 is missing from the printed text.

Phase-Shift Analysis of High-Energy p-p Scattering Experiments, A. GARREN [Phys. Rev. **92**, 213 (1953)]. To fit the experimental data, the value of $[\eta_A\eta_B]^{\frac{1}{2}}$ quoted in this Letter should be $\pm0.30\pm0.08$ rather than 0.40 ± 0.12. (Also, the column labeled η in Table I should have been labeled $-\eta$.) The phase shifts consistent with this value are shown in the accompanying table. Correspondingly, the shaded area in Fig. 1 should be a little lower on the diagram.

TABLE I. Some phase shifts (in degrees) at 213 Mev consistent with isotropy, $\sigma(\theta)=4.97$ mb/sterad, $\eta=-0.30\pm0.08$.

δ_1^2	δ_1^0	δ_1^1	δ_0^0	$-\eta$
− 5	70	−4.1	36	0.237
− 5	80	−0.2	31	0.256
− 5	90	5.1	28	0.267
− 5	95	10.1	23	0.275
− 5	95	16.4	5	0.297
−10	40	−6.1	55	0.251
−10	50	−5.4	46	0.340
−10	−10	29.8	36	0.249
−10	0	36.7	14	0.339
−15	30	−3.2	46	0.261
−15	35	−3.6	39	0.327
−20	20	1.0	49	0.235
−20	30	−0.6	42	0.387
−25	0	13.9	27	0.287
−25	10	7.3	33	0.256
−25	20	3.8	30	0.368