(A5) and (A6) into (A3) and integrating over $\cos\theta_D'$, we have Eq. (7) in Sec. V.

In order that the integral in Eq. (A3)$\neq 0$, we must have

$$(b-2\alpha P_D+P_D^2)^{\frac{1}{2}}\leq a\leq (b+2\alpha P_D+P_D^2)^{\frac{1}{2}}. \quad \text{(A8)}$$

$P_{\min}$ and $P_{\max}$ are deduced from Eq. (A8). The results are

$$P_{\min}=|\alpha-(\alpha^2-\mu)^{\frac{1}{2}}|,$$
$$P_{\max}=\alpha+(\alpha^2-\mu)^{\frac{1}{2}}, \quad \text{(A9)}$$

where

$$\mu=4ME_p+2E_\gamma(-\tfrac{1}{2}P_p+E_p-M)+2B(E_\gamma-E_p+M).$$

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Photodissociation of the μ Meson

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The cross section for the production of a charged vector boson by the dissociation of a high-energy μ-meson beam undergoing Coulomb scattering has been calculated. The cross section for such a process is $(1-3)\times 10^{-34}$ cm^2 in Pb. Possible experiments for the detection of such decays are discussed.

In the papers of Good and Walker[1] the possibility of the photodissociation and diffraction dissociation of high-energy beam particles is pointed out. In general, the study of photoprocesses serves as a complement to other means of study of strong interactions (e.g., π-meson scattering vs photoproduction). Thus, so far as the strong interactions are concerned, the Coulomb disintegration will probably serve as a complementary tool to diffraction dissociation. In the case, however, of weak interactions, the Coulomb disintegration of beam particles may be one of the few tools other than a study of decay processes available for probing the nature of the weakly interacting particles. The μ meson is probably the most enigmatic of the fundamental particles and, consequently, the ability to photodissociate the μ meson represents an exciting possibility. We have made a calculation of the photodissociation of the μ meson using a specific model. The model is the one in which the weak interactions are mediated by a charged vector boson.[2,3] This calculation is much simpler than the corresponding ones for strongly interacting particles, since presumably one may apply the usual perturbation theory treatment to the problem.

The cross section for the production of the intermediate boson and a neutrino by unpolarized μ mesons of energy E incident on a nucleus of charge Ze has been calculated using the Weizsäcker-Williams approximation. Accordingly, the cross section for photoproduction of B (vector boson) and neutrino by a photon of momentum q incident upon a μ meson at rest has first been calculated in lowest-order perturbation theory for both the weak boson-lepton interaction and the electromagnetic interaction. The result is

$$\begin{aligned}
\sigma(q)&=a(q)(\lambda-2)^2+b(q)(\lambda-1)+c(q),\\
a(q)&=(\alpha g^2/32M_B^2)(\ln x+\tfrac{1}{2}-x^{-1}\ln x-x^{-1}+\tfrac{1}{2}x^{-2}),\\
b(q)&=(\alpha g^2/8M_B^2)(2-3x^{-1}\ln x-x^{-1}-2x^{-2}),\\
c(q)&=(\alpha g^2/8M_B^2)(-x^{-1}\ln x+3x^{-1}-2x^{-2}\ln x\\
&\qquad -2x^{-3}\ln x-3x^{-3}),
\end{aligned} \quad (1)$$

with M_B the boson mass and λ the *total* magnetic moment of the boson. Here $x=q/q_m$ is the photon momentum in units of the threshold momentum q_m. Note that the cross section diverges for large q unless $\lambda=2$. The threshold momentum q_m is given by

$$q_m=M_B^2/2m,$$

with m the μ-meson mass. The boson-lepton interaction is taken as

$$\mathfrak{L}_{B-l}=-g\bar{\psi}_\mu\gamma_\rho\varphi_\rho\tfrac{1}{2}(1+\gamma_5)\psi_\nu+\text{H.c.}+\text{electron terms},$$

so that the coupling constant g is determined by

$$g^2/M_B^2=4\times 10^{-5}/M_n^2. \quad (2)$$

Various terms of order m^2/M_B^2 relative to the main terms in Eq. (1) have been dropped.

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TABLE I. Cross section values, in units of 10^{-34} cm^2.

E (Bev)	A	B	C	σ_n
25	0.01	0.03	0.54	0.55
100	0.74	1.40	2.38	3.12
200	1.86	3.60	3.12	4.98

If the above expression is integrated over the appropriate photon distribution corresponding to the nucleus Z moving with velocity v, and then the results transformed back to the system with Z at rest, there results

$$\sigma_T = A(\lambda-2)^2 + B(\lambda-1) + C,$$

$$A = [(Z\alpha)^2 g^2/32\pi M_B^2][\tfrac{1}{3}\ln^3 x_0 + \tfrac{1}{2}(1+2\ln\beta)\ln^2 x_0 - \tfrac{1}{2}(7-2\ln\beta)\ln x_0 - 2(1-\ln\beta)x_0^{-1}\ln x_0 + 2(3-2\ln\beta)(1-x_0^{-1}) + \tfrac{1}{4}(-1+2\ln\beta)(1-x_0^{-2})],$$

$$B = [(Z\alpha)^2 g^2/8\pi M_B^2][2\ln^2 x_0 - (9-4\ln\beta)\ln x_0 - 6(1-\ln\beta)x_0^{-1}\ln x_0 + (14-8\ln\beta)(1-x_0^{-1}) + \tfrac{1}{2}(1-2\ln\beta)(1-x_0^{-2})],$$

$$C = [(Z\alpha)^2 g^2/8\pi M_B^2][(13/9)\ln x_0 - 2(1-\ln\beta)x_0^{-1}\ln x_0 - 2(1-2\ln\beta)(1-x_0^{-1}) - \tfrac{1}{4}(1-2\ln\beta)(1-x_0^{-2}) + (2/27)(13-21\ln\beta)(1-x_0^{-3}) - (1-2\ln\beta)x_0^{-2}\ln x_0 - \tfrac{4}{3}(1-\ln\beta)x_0^{-3}\ln x_0]. \quad (3)$$

Here x_0 = maximum value of $x = q_{\max}/q_m$ and $x_0 = (2\gamma/\beta) \times (m/M_B)^2$. $\beta = mb_m$ is m times the minimum impact parameter (the nuclear radius).

Since the photoproduction cross section diverges for large q, all terms except the dominant term in a high-energy expansion are sensitive to the way in which the photon distribution is cut off at large q. The photon distribution used here is cut off at $q = 1/b_m$, where b_m is the nuclear radius. This procedure seems to work quite well in the problem of bremsstrahlung by a fermion with an anomalous magnetic moment. The cross section given above therefore agrees only asymptotically with that neutrino absorption cross section calculated by Lee and Yang,[4] who used a cutoff based on the electron scattering form factors. It may be remarked that the lower order terms are important at μ meson energies up to about 100 Bev.

If the mass of the boson is taken to be about a nucleon mass, for purposes of calculation, then the minimum photon energy q_m is 4.1 Bev. Taking the minimum impact parameter as the radius of the nucleus Z, implies for Pb that $\beta = 4.5$. Then the threshold μ energy for the production of a boson of nucleon mass in scattering off Pb is about 18.5 Bev. This threshold rises quadratically with the boson mass. The coefficients A, B, C in expression (3) for the total cross section may be calculated as functions of energy. Table I gives values of these three quantities at μ energies of 25, 100, and 200 Bev, as well as the total cross section σ_n for a boson of "normal" magnetic moment, $\lambda = 1$, again for $M_B = M_n$ and scattering off Pb. The mass of the boson, if it exists, is unknown, and the failure to observe such processes can of course only put a lower limit on the mass.

The above considerations have assumed an unpolarized μ beam. If the μ's are longitudinally polarized, the only effect is to double all cross sections.

As far as experimental work is concerned, the sort of thing that would be observed experimentally would be an anomalously large energy loss of a μ or the disintegration of a μ into an electron and two neutrinos. The former case would correspond to $\mu^+ + {}_ZN^A \rightarrow B^+ + \bar{\nu} + {}_ZN^A$ and then $B^+ \rightarrow \mu^+ + \nu$. The process with which this competes would be the bremsstrahlung and electron pair production of μ mesons. The cross section for the bremsstrahlung process in lead in which more than $\frac{1}{2}$ the energy of the μ is lost is $\sim 10^{-27}$ cm^2 as compared to $(1-3)\times 10^{-34}$ cm^2 for the dissociation of the μ. There are other processes in which the μ induces photoprocesses by virtue of its Coulomb field. The cross section for these processes would be perhaps a factor of 10 less than the bremsstrahlung process.

The dissociation process looks like a bremsstrahlung process in which the μ radiates two neutrinos, i.e., we have an anomalous loss of energy of the μ. In order to detect such a process one has to discriminate very efficiently (an inefficiency $<10^{-7}$ in the detection of a 10 to 50-Bev γ ray) against the bremsstrahlung process or pair process. The experiment as proposed seems to be feasible but extremely difficult at either the CERN or Brookhaven alternating gradient synchrotrons. The experiment probably cannot be done by counter techniques alone because of the discrimination against background processes required. Some combination of a visual technique and counter controlling is necessary, together with weeks of running time.

Even though the results seem rather discouraging so far as experiments are concerned, it would seem worthwhile at least to attempt such an experiment, since our lack of understanding of μ mesons makes any calculation of this sort unreliable.

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