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ON POSSIBLE IMPLICATIONS OF A LARGE $\sigma_T(e^+e^- \to \text{hadrons})$*

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ABSTRACT

Based upon the notion that the large cross section observed in $e^+e^- \to$ hadrons may be due to a kind of hadronic core inside the electron, it is suggested that there may also be a large cross section for $e^-e^- \to$ hadrons and further that lepton number may not be conserved in the latter reaction.

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The anomalously high ratio of the total hadronic cross section $\sigma_T(e^+e^- \to$ hadrons), henceforth denoted by σ_{hb}^{+-} (where the subscript b signifies "background" only [1]), to $\sigma(e^+e^- \to \mu^+\mu^-)$, found at CEA [2] and SPEAR [3], at beam energies $E_0 > 1.5$ GeV, possibly leads to difficulties and complications for the hadronic quark-parton models. As a consequence, the literature now abounds with models attempting to cope with these difficulties, including one which questions the conservation of baryon and lepton numbers [4,5]. Since it is not clear at present whether or not these efforts will ultimately be successful, it is still of interest to think about other approaches. The large cross section, $\sigma_{hb}^{+-} \sim 20$ nb (prior to the recently discovered line structure [6-8]), has led to the suggestion that the electron may have intrinsic hadronic aspects; this cross section is then visualized as due to a "strong" interaction with a range on the order of 10^{-16} cm forming a kind of hadronic core inside the electron [3]. On the other hand, $\sigma(e^+e^- \to \mu^+\mu^-) \sim 1/E_0^2$ in accord with QED predictions [9].

While we await more data from SPEAR (e^+e^- to 4.2 GeV) and DORIS (e^+e^- and e^-e^- to 5 GeV), which presumably will help clarify the situation, novel and intriguing speculations come to mind.

First we note that the notion that σ_{hb}^{+-} (for $E_0 > 1.5$ GeV) is due to a hadronic core inside the electron suggests that this (annihilation) process may proceed through a coupling independent of the electric charge. And, consistent with this idea, the "constant" [10] cross section suggests that we may be in a regime analogous to that in hadron physics in which particle and antiparticle cross sections become flat and tend toward the same asymptotic value [11,12]. One intriguing speculation, then, is if this geometric notion is an appropriate description of σ_{hb}^{+-}, then should not σ_{hb}^{--} be comparable to σ_{hb}^{+-} for $E_0 > 1.5$ GeV [13]

A further point should be made. In the geometric picture of a strong, short range force, the interaction must proceed via an S wave; if $E_0 < 200$ GeV, a quantized orbital angular momentum > 0 requires an impact parameter > 10^{-16} cm, i.e., outside the range of the assumed interaction. The $^3S_1$ would be associated with a $J^{PC} = 1^{--}$ initial state (but not necessarily going through a virtual photon) while the $^1S_0$ with a 0^{-+}. The latter state is charge symmetric (implied by C = +1) and therefore would seem to be the more appropriate state to associate with an interaction which does not depend upon electric charge [14].

It appears that the first available experimental information which will bear directly on the possibility that part of σ_{hb}^{+-} may be associated with a pseudoscalar initial state [15] will be a variation of the cross section due to a (presumed) time dependent increase in beam polarization [16]. While at SPEAR I the polarization time constants were too long, relative to the data-taking runs, for any such effect to be observable, at SPEAR II the polarization time constant, which goes like E_0^{-5}, will (at $E_0 = 4$ GeV [17]) be as short as 10 min.

Finally, if, due to a hadronic core in the electron, the above geometric view is appropriate, then we are faced with a new kind of lepton-hadron interaction [18]. This leads to the most intriguing speculation of all: If there is a new lepton-hadron interaction responsible for σ_{hb}^{+-}, does it respect lepton number? Since leptons are not manifest in the final state of $e^+e^- \rightarrow$ hadrons, and if charge symmetry in fact obtains, then one would expect no leptons in the final states of $e^-e^- \rightarrow$ hadrons.

I wish to thank S. J. Brodsky for stimulating discussions on this topic, J. D. Bjorken and B. Richter for some important comments, and J. C. Pati for a discussion about various ramifications of the Pati-Salam model. I am also grateful to P. C. M. Yock and A. H. Rogers, Jr., for useful comments.

REFERENCES AND FOOTNOTES

[1] This letter does not address itself to the spectacular but unexpected structure in e^+e^- annihilation which has recently been found at SPEAR [6], Frascati [7], and DESY [8], although it is certainly conceivable that this structure may be related to the large σ_{hb}^{+-} and the postulated "strong" force of the electron. We are focusing here on what is now thought of as the "background" level of $\sigma_T(e^+e^- \to \text{hadrons})$ and not its structure. Consequently we use σ_{hb}^{+-} to denote only this background level after the structure has been subtracted out.

[2] A. Litke et al., Phys. Rev. Lett. 30 (1973) 1189; G. Tarnopolsky et al., Phys. Rev. Lett. 32 (1974) 432.

[3] B. Richter: Invited talk at the Irvine Conference, December 1973; invited talk at the APS Annual Meeting, Chicago, February 1974; Plenary Session Report, XVII Int. Conf. on High Energy Physics, London, July 1974 (SLAC-PUB-1478, September 1974).

[4] J. C. Pati and A. Salam: Phys. Rev. D8 (1973) 1240; Phys. Rev. Lett. 31 (1973) 661; Phys. Rev. Lett. 32 (1974) 1083.

[5] The expected rate for reactions which violate lepton number in the Pati-Salam theory is small and would not lead to the relationship $\sigma_{hb}^{--} \sim \sigma_{hb}^{+-}$ suggested in this letter; J. C. Pati, private communication.

[6] J.-E. Augustin et al., Phys. Rev. Lett. 33 (1974) 1406; G. S. Abrams et al., Phys. Rev. Lett. 33 (1974) 1453.

[7] C. Bacci et al., Phys. Rev. Lett. 33 (1974) 1408.

[8] DASP Collaboration, DESY report 74/59 (1974), submitted for publication; L. Criegee et al., DESY preprint (1974), submitted for publication.

[9] R. Gatto, Springer Tracts in Modern Physics 39 (1965) 106.

[10] In contrast with the earlier results, a more detailed analysis of the data indicates that σ_{hb}^{+-} for $E_0 > 1.5$ may not actually be constant (J.-E. Augustin et al., SLAC-PUB-1520, LBL-3621, January 1975, to be published), but the logic of this letter rests more on the fact that σ_{hb}^{+-} is large than that it is constant.

[11] I. Ia. Pomeranchuk, Sov. Phys.-JETP 7 (1958) 499.

[12] This analogy is less than perfect, however, since, as is discussed below, the assumed very short range precludes higher orbital angular momenta, i.e., precludes forward diffraction phenomena. The data [3] also do not support an underlying forward diffraction mechanism.

[13] A speculation similar to one of this paper ($\sigma_{hb}^{--} \cong \sigma_{hb}^{+-}$, asymptotically for large E_0) has been reached independently, using a somewhat different line of reasoning, by S. Minami, Osaka City University Preprint, September 1974.

[14] We also note that the $^1S_0$ state is the only initial (S-wave) state which is suitable for the hypothesis that σ_{hb}^{--} is large, since the Pauli exclusion principle prevents e^-e^- from existing in a $^3S_1$ state. Consequently, one would anticipate that σ_{hb}^{--} might not be as large as σ_{hb}^{+-}. Another factor which might tend to reduce σ_{hb}^{--} below σ_{hb}^{+-} is that there are fewer available isospin states due to the double charge.

[15] It is only proper that we point out that estimations of pseudoscalar meson decay rates (e.g., $\pi^0 \to e^+e^-$) have been made indicating possible theoretical difficulties with the postulation of a pseudoscalar initial state for σ_{hb}^{+-}. See, e.g., I. I. Y. Bigi and J. D. Bjorken, SLAC-PUB-1422, May 1974; J. D. Davies, J. G. Guy, and R. K. P. Zia, Rutherford Laboratory Preprint R1-74-092 (1974). However, it is not clear that these estimates

apply to the (possible) new kind of lepton-hadron interaction contemplated here.

[16] T. Goldman and P. Vinciarelli, Phys. Rev. Lett. 33 (1974) 246, who suggest the possibility of a scalar intermediate state in e^+e^- hadrons, point out that in the pseudoscalar case the rate should increase by a factor of two as the beams progress after the fill from unpolarized to (an assumed) full transverse polarization. In addition to a time variation of (the pseudoscalar part of) σ_{hb}^{+-}, one would expect to observe dips in σ_{hb}^{+-} as a function of E_0 due to resonant machine depolarization effects. We remark in passing that, if present, the location of these dips would furnish an extremely accurate energy calibration for the machine.

[17] See R. Schwitters, Nucl. Instr. and Meth. 118 (1974) 331, for the relevant SPEAR parameters and references to the earlier literature on the radiative polarization of electron beams in storage rings.

[18] The "constant" cross section from CEA and later from SPEAR has led others to consider the idea of a new, short range lepton-hadron interaction. For example, O. W. Greenberg and G. B. Yodh, Phys. Rev. Lett. 32 (1974) 1473; D. V. Nanopoulos and S.D.P. Vlassopulos, Nuovo Cimento Lett. 10 (1974) 751; R. Chanda, Nuovo Cimento Lett. 11 (1974) 593. But these papers do not consider the σ_{hb}^{--} question.