18, 665 (1973), reaction (1) and (6) at 102 GeV/c; the ANL, NAL, ISU, MSU, UM collaboration, L. Hyman *et al.*, Bull. Am. Phys. Soc. 18, 666 (1973), reaction (1) at 205 GeV/c; E. L. Berger *et al.*, Phys. Rev. Lett. 29, 675 (1972), reaction (1) at 21 GeV/c; Brown University report (A. Shapiro, private communication), reaction (2) and (5) at 4.1 GeV/c; Bonn-Hamburg-Munich collaboration (V. Blobel, private communication), reaction (6) at 12 GeV/c and 24 GeV/c.

[3] We have also examined data for other pion-production reactions at high energies. In particular, the cross section for $\pi^- p \to \pi^-$ + anything has a dependence very similar to that observed for reaction (5). The other available channels, viz., $K^- p \to \pi^+$ + anything (two experiments) and $\pi^- p \to \pi^+$ + anything (three experiments) suffer from the presence of proton background in the final states and are consequently difficult to measure at $p_t^* = 0$, and the meager data that exist for these reactions may be inconsistent with each other. We note, however, that in both reactions there is one data point grossly inconsistent with the general energy trend observed for the other channels displayed in Fig. 1.

[4] The references for previous K_S^0 and Λ^0 data can be found in the review by T. Ferbel, in *Proceedings of the Third International Colloquium on Many Body Reactions, Zakopane, 1972,* edited by A. Białas *et al.* (Cracow, Poland, 1972). The new data are from the NAL-UCLA collaboration, as reported by R. Engelmann, Bull. Am. Phys. Soc. 18 (1973), reactions (7) and (11) at 303 GeV/c; G. Charlton *et al.*, Phys. Rev. Lett. 30, 574 (1973), reactions (7) and (11) at 205 GeV/c; A. Seidl *et al.*, Bull. Am. Phys. Soc. 18, 665 (1973), reactions (7) and (11) at 102 GeV/c; Soviet-French collaboration report (unpublished) reactions (7) and (11) at 69 GeV/c; Notre Dame report (unpublished) (P. Stuntebeck, private communication), reactions (10) and (14) at 18.5 GeV/c. The entry from CERN Intersecting Storage Rings (ISR) energies in Fig. 2 is estimated from the review of E. Lillethun, Bergen Report No. 47, 1972 (unpublished), assuming that K^- production is the same as K_S^0 near $p_t^* = 0$.

[5] See references given in Ref. 4. The Λ^0 inclusive cross section contains the sum of the Λ^0 and Σ^0 cross sections.

[6] The total cross sections used here are the same as given previously in T. Ferbel, Ref. 4, namely, 39.8 mb, 23.4 mb, 17.4 mb, 99 μb, and 22.9 mb, respectively, for pp, $\pi^+ p$, $K^+ p$, γp, and $K^- p$ channels.

[7] This is equivalent to $s^{-1/4}$ for high energies; see Ref. 1.

[8] In this regard, see the compilation of H. Meyer and W. Struczinsky, DESY report, 1972 (unpublished). In particular, note the low-energy behavior of $\gamma p \to \pi^+$ + anything which contains sizable contributions from vector-meson production and proton fragmentation.

[9] We note that these naive remarks assume that new phenomena which may appear at higher energies will not void all the conclusions we reach from presently measured data. The growth of the total pp cross section at ISR energies in particular, certainly raises very interesting questions concerning the meaning of all the results we have presented. See University of Rochester Report No. UR429 (to be published in Ann. N. Y. Acad. Sci.) for further comments concerning asymptotic behavior.

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Suitability of Nuclear Emulsion for Nuclear-Structure Studies at a High-Energy Muon Facility*

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Recently Jain and Stern reported nuclear photographic emulsion to be particularly suited for nuclear-structure studies at high-energy muon facilities. Significant discrepancies between their results and our own are presented and discussed.

In a recent report[1] published under the editorial policy announced July 20, 1964,[2] Jain and Stern claim to present a study of the giant-resonance (GR) phenomenon in interactions of high-energy muons with photographic emulsion nuclei—a phenomenon first studied in nuclear emulsion using high-energy beam muons by Kirk *et al.*[3] The conclusion of Ref. 1 is that the interactions of high-energy muons with emulsion nuclei can be used for the study of nuclear structure. Of course, the study of nuclear structure requires that the identity of the target nucleus be known. The argument that nuclear emulsion would make an ideal target-detector system rests on a method reported in Ref. 1

to distinguish between events involving light nuclei and those involving heavy nuclei, thereby reducing the ambiguity of the target nucleus to an uncertainty between Ag and Br for the heavy and C, N, and O for the light. The study included only events whose vertices were formed by one black prong in addition to the incident and scattered muon tracks,[1] so-called (1 + 1) events. In our laboratory, we have been involved in a long-range study of a variety of muon-induced interactions in nuclear emulsion and have found a number of serious discrepancies between our results[4,5] and those presented in Ref. 1.

1. The method used in Ref. 1 to distinguish between interactions with light- and heavy-target nuclei consisted in labeling any (1 + 1) event with a clear vertex as an interaction with a light nucleus. With this criterion, roughly 25% of the (1 + 1) events, where the black prong was identified as a proton, were labeled as interactions with light nuclei. The remaining 75% of the (1 + 1) events, with protons, were found to have a blob or recoil (a short, black, thick track of length 5 μm) which labeled them as interactions with heavy nuclei. Neither justification for the use of these criteria nor any estimate of either the reliability or accuracy of these identifications was given in Ref. 1.

An examination in our laboratory of 46 (1 + 1) events induced by 5.0-GeV/c μ^+ in Ilford G-5 emulsion resulted in only five event vertices that had identifiable blobs or recoils. To exclude any bias against such events, all events in which the black prong extended at least one developed grain diameter (≥ 0.5 μm) beyond its intersection with the muon's trajectory were included in the count. The remaining 41 events appeared to have clear vertices.

Although our result is in disagreement with Ref. 1, it appears to be consistent with earlier studies of emulsion stars produced by stopping π^- (Refs. 6–8) and K^- (Refs. 9–12), which also used blob-recoil criteria to separate light- from heavy-target nuclei. Since the energy absorbed in the form of a stopping pion (140 MeV) is greater than the energy transfer in a typical GR event (10–50 MeV), the subsequent recoils should be considerably longer and more likely to be observed. Yet, Cheston and Goldfarb report[6] that only 43% of the stopping π^- events with one black prong were observed to have recoils, although about 80% (Refs. 7 and 8) of these events result from absorptions by heavy nuclei.

We conclude, therefore, that the observation of a clear vertex as used in Ref. 1 is not reliable evidence of an interaction with a light nucleus.

2. Thickness and stopping behavior of tracks were extensively used in Ref. 1 to distinguish tracks of protons from those of deuterons and heavier particles. Our experience[13] leads us to suspect any identifications of tracks based on thickness and stopping behavior alone. This is in agreement with Powell *et al.*[14] who state that discrimination between protons and deuterons by inspection is impossible. We recommend use of the constant sagitta method for *all* identifications.

3. Jain and Stern report a structure in the secondary proton kinetic-energy spectra shown in Figs. 1(a) and 1(b) of Ref. 1 that does not appear to be warranted by the statistics. Such an effect would be definitely established only if the differences in the number of events (N) in adjacent bins were the order of two or three standard deviations. In Ref. 1 the number of events in a bin is typically $N \sim 10$ to 15; three standard deviations would be $3N^{1/2} \sim 10$. Generally the dips are not this large. In all cases the dips extend over only one energy bin.

The energy spectrum of evaporation prongs from emulsion nuclei is known[15] to also peak near 8 MeV. Consequently it is difficult to see how Figs. 1(b) and 1(c), by themselves, are evidence of proton emission by GR decay. In a recent comparison[5] of (1 + 1), (2 + 1), and (3 + 1) events produced by 5-GeV/c muons in Ilford G-5 emulsion, the kinetic-energy spectra of the black prongs were found to be similar, although the distribution in four-momentum transfer for the (3 + 1) events was found to be clearly different.

The above arguments lead us to conclude that nuclear emulsion as used in Ref. 1 unfortunately falls far short of being an "ideal target-detector system" for studying nuclear structure. Even if it was possible to unambiguously separate protons emitted by heavy nuclei from those emitted by light nuclei, the resulting measured energy spectrum would still be the superposition of interactions with Ag and Br nuclei; the events involving light nuclei, of course, would be the superposition of C, N, and O nuclei. In view of the better techniques already in use for examining the excited states of particular nuclei, including the use of nuclear emulsion with a known target, the knowledge of the nuclear structure of a mixture of nuclei would hardly be of significant interest for nuclear-structure studies.

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New Approach to Relations Between Deep-Inelastic Structure Functions

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It is argued that symmetry properties available from experiments outside deep-inelastic physics can provide guidance for understanding the structure functions in the deep-inelastic region. In particular, it is suggested that the component of the current that transforms like the "ϕ" is more weakly coupled to nonstrange hadrons than the components which transform like the "ρ" or "ω". This leads to a stringent upper bound for the sum of the electromagnetic structure functions, $F_2^{\gamma p} + F_2^{\gamma n}$, which can be tested by experiments.

The theoretical descriptions used to obtain relations between deep-inelastic structure functions are generally not very restrictive, because they are either too general or too specific. General treatments place weak bounds on structure functions that at the moment are in no danger of violation by experiment. Specific models with detailed assumptions give predictions whose experimental violation can always be explained.

The general models do not exclude pathological cases like a quark-parton model of the nucleon with three valence quarks and an infinite sea of *strange* quark-antiquark pairs. This strange-quark sea can dominate the electromagnetic functions. Thus these models cannot give upper bounds on the ratio of electromagnetic to neutrino structure functions. They only give lower bounds which turn out to be rather trivial.

The general models also tend to disregard information already available from experiments outside deep-inelastic physics, such as the SU(3) properties of the electromagnetic current. The ratio 9 : 1 : 2 for the strengths of the components of the photon which transform like the vector mesons ρ, ω, and ϕ is predicted[1] by the classification of the photon as the U-spin scalar component of an octet, and the canonical ω-ϕ mixing angle. This ratio is very sensitive to the presence of a possible SU(3) singlet component. In the Sakata model which has such a singlet component, the ratio is changed from 9:1:2 to 1:1:0, which is far outside experimental limits, from experiments of e^+e^- annihilation into vector mesons[2] and vector-meson photoproduction.[3] Yet some general treatments of deep-inelastic processes give predictions[4] with coefficients depending "on the parton charge" and quote values for the Sakata model. They do not note that such variations in parton charge imply