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BROOKHAVEN NATIONAL LABORATORY
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Upton, New York

ACCELERATOR DEPARTMENT
Informal Report

ISABELLE PROJECT NON-HADRONIC INTERACTION STUDY GROUP

INTERIM REPORT

W.J. Willis

September 14, 1971

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INTERSECTING STORAGE ACCELERATOR NOTES

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Introduction

This report has been prepared to summarize the conclusions to date, and this draft has not yet been circulated among the members of the study group.

The discussions on these interactions have a very different character from those on strong interactions in storage rings. One can make a long list of hadronic interactions which can almost certainly be performed, and then set about design studies to establish the best configurations for the decay region, etc. The first task for the group considering the other interactions is to decide if there are any significant measurements which can be made, with reasonable accelerator parameters. We find reason to believe that most important experiments can be done, though there are some serious qualifications which must be made at this time, pending more information from the accelerators just now starting up.

First we must mention the class of reactions which violate some rule characteristic of the strong interactions, for example isospin, strangeness, or parity conservation. Several experiments of this type have been proposed. A search for baryons produced with non-zero helicity, implying parity violation, may stand as an example. Now, these experiments seem most valuable

and interesting, but it seems to be true in general that they will not be sensitive to the kind of effects predictable on the basis of our present understanding of the weak interactions. Thus, if a positive effect were found, it might finally be concluded that it signals a breakdown of parity conservation in the strong interactions, the appearance of some new interaction, etc. New discoveries of this sort would be one of the most exciting results from the new machine, but we understand our task as seeing which results may be reasonably expected within the framework of presently known, or guessed, physics.

Furthermore, we recognize that although e-p collisions could be provided as an extra option, the experimental possibilities at the outset will probably be limited to p-p storage rings. This immediately raises the question of whether there are any feasible experiments dealing with the weak or electromagnetic interactions which can overcome the background of hadronic processes. One answer to this question has been provided by Lederman, set forth in some detail in CRISP Report 71-29 by Leon M. Lederman. It starts from the fact that, at the AGS, the electromagnetic process of muon pair production has been observed, with a substantial cross section. The interest in this sort of reaction in the high energy storage rings is presumably in the possibility of extending the data to high effective masses, or large time-like momentum transfers. Since present data exist only for one, relatively low, proton energy, we have no experimental basis whatsoever for extrapolating the cross section to large energy (S) and momentum transfer (Q). Lederman makes the assumptions that for large S and Q the cross section depends only on the dimensionless combination Q^2/S , and that the AGS experiment was already in the region where the scaling in this variable was valid. Then one predicts a cross section for pairs of mass 15 GeV/c² of about 10^{-35} cm², or 10^{-36} cm² for a mass of 35 GeV/c².

Of course, if there is a negative metric heavy photon as suggested by Lee and Wick, it can lead to much larger cross sections for effective masses near its mass. Also, if there should exist other heavy charged particles, they can be produced with cross sections comparable to electrons and muons.

Furthermore, the Conserved Vector Current hypothesis allows one to predict the cross sections for weak reactions. On this basis, the cross section for production of an intermediate vector boson, W , is up to more than 10^{-33} cm^2 for masses above $100 \text{ GeV}/c^2$, for 200 GeV storage rings. The cross section for the inclusive four-fermion weak reaction, $p + p \rightarrow e + \nu + \text{anything}$, may also be predicted, and is of the order of 10^{-35} cm^2 . This reaction will be particularly important to study if no W is forthcoming, since it will contain the secret of how the weak interactions respect unitarity at high energy. The present theory predicts a constant value for this cross section, differential in effective mass. Some new behavior must become evident as this mass approaches $300 \text{ GeV}/c^2$.

The experimental detection of all these processes seems to be possible as far as the background from strong interactions is concerned, on the assumption that large momentum transfers are very strongly suppressed in the strong interactions. All the above processes produce charged leptons at large momentum transfers for a substantial fraction of the events. The problem, then, is to obtain a luminosity sufficient to obtain a reasonable rate, say a few counts per hour before efficiency factors are put in. This requires a luminosity of the order of $10^{33} \text{ cm}^{-2} \text{ sec}^{-1}$, at least. The requirements on the intersection region do not seem to be too severe. The particles of interest emerge at substantial angles so that long magnet-free spaces are not necessary. A small or zero intersection angle is desirable to get the highest luminosity but the design of the detectors, which must cover a large solid angle, will become

difficult if the intersection region is more than about a meter long. This points to the use of the strongest possible focusing.

The trouble with the picture outlined above is that the predictions of the cross sections may be too high by many orders of magnitude. It behooves us to inspect more closely reactions which are at first sight less promising. Note that the momentum transfers to which scaling is applied in lepton pair production are time-like, while the kind of scaling which has been found at SLAC is for space-like momentum transfers, and for a different process at that. If we could study $e^- + p \rightarrow e^- + \text{anything}$, and $e^- + p \rightarrow \nu + \text{anything}$, we would have an experimental base on which to base our extrapolations. If the time-like kind of scaling is found to fail, the e-p options may receive a high priority, but in this report we will not discuss them any further.

One other possibility seems to exist for the p-p storage ring, and that is to study those interactions where very large momentum transfers are produced, but without production of massive pairs of leptons. It is possible to see this, although in a model dependent way, as similar to the e-p scattering, but with the hadron vertex on both sides and a photon or W exchanged, leading to a relatively weak dependence on Q in the deeply inelastic region falling as Q^{-4} and Q^0 respectively. If the events caused by hadron exchange fall off exponentially, or perhaps as Q^{-8} , then successive regions in Q will be dominated by the strong interactions, the electromagnetic interactions, and the weak interactions, assuming that the latter two obey scaling for space-like momentum transfers. It is necessary to decide how one may define Q with the least model dependence, and a report generated within our study group indicates one way in which this can be done. An estimate for the weak component of the cross section, which may dominate for momentum transfers greater than $\sim 70 \text{ GeV}/c$, is about 10^{-35} cm^2 .

Of course the mere observations of the cross section as a function of momentum transfer will not conclusively identify the nature of the interaction. For this reason, it will be very desirable to make tests of I-spin dependence, and charge independence, as a function of Q . We may expect that the former appears and the latter fails when the strong interactions cease to dominate the cross section. In order to make these measurements, it will be essential to study p-d and d-d collisions, but this is relatively easy.

In summary, we can look forward to a very interesting series of experiments on the non-hadronic interactions, although the answers will probably be very different from our predictions.

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M. Goldhaber, L.J. Haworth, G.H. Vineyard