FUTURE NEUTRINO EXPERIMENTS WITH THE CERN HEAVY LIQUID BUBBLE CHAMBER

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I. INTRODUCTION

The 1963-64 series of ν runs were carried out using a freon filled chamber of 500 litres actual volume. A fiducial volume of 220 litres was applied in order to obtain good measurability, particle identification and γ-ray detection, as events were classified qualitatively.

In the past few months a new chamber body has been constructed, having a volume of 1,130 litres, which on applying the same fiducial criteria as with the previous chamber, gives a fiducial volume of 660 litres. As this chamber is still contained within the ν-beam diameter the ν-interaction rate will be increased by a factor of three.

All ν runs have been carried out in heavy freon (CF_3Br). This liquid has but one virtue; a density of 1.5. Our previous analysis has shown that it is extremely difficult to identify various interaction types because of secondary interactions within the parent nucleus.

Thus, if any further experiment in freon is contemplated it must be to study processes whose interpretation is unaffected by secondary interactions.

Such an experiment is to be found in an $\bar{\nu}$ exposure. Here, several questions can be studied:

a) Hyperon production

The total rate of production of hyperons and hyperon resonances by elastic and quasi-elastic processes can be determined. In these reactions a large number of secondary interactions will occur; Σ's will charge exchange and give Λ's, Y^*'s will decay within the parent nucleus and half the pions will be absorbed, etc. However, in all cases the strangeness will manifest itself.

No confusion will arise from the inelastic events involving associated strange-particle production, as these events occur above 4 GeV, whereas the elastic and quasi-elastic occur between 0-3 GeV. As the theoretical predictions indicate a production of $\sim$ 7% of the elastic and N^* processes, an experiment giving 1 $\sim$ 200 events of these latter processes will resolve the question.

With the present set-up of 23 m iron shielding, 24.5 GeV and 3 sec repetition rate, we expect $\sim$ four events/day of the elastic and N^* type.

b) N^* production

The N^{*-} should be produced relatively frequently in the $\bar{\nu}$ experiment, and can be used to obtain information on the N^* form factor. N^{*-} (produced in the $\bar{\nu}$ experiment) and N^{*++} (produced in the ν experiment) of the same momentum should be absorbed almost equally. That is, events with the same q^2 should have the same absorption probability. As the ν and $\bar{\nu}$ spectra are well calibrated between 0-3 GeV (where the majority of the events occur) then the ratio $(dN_\nu/dq^2)/(dN_{\bar{\nu}}/dq^2)$ as a function of q^2 essentially gives $F_A.F_V$.

c) Elastic production and form factors

Here, as in the ν experiment, the main difficulty will be the extraction of the true elastic sample. However, from the knowledge gained from the ν events it will be possible to subtract the inelastic contamination by using the observed events with a single π^-. Thus, by using the $\bar{\nu}$ sample, combined with the ν results and spectral information, we predict that the error in the form factor determination will finally be of a systematic and not statistical nature.

II. EXPERIMENTS WITH FREE-NUCLEON TARGETS

It is apparent that to progress further in neutrino physics one needs to work with free nucleon targets. These can be furnished by using hydrogen or hydrocarbons, and we will discuss those experiments which lend themselves well to the properties of hydrocarbons. These properties are the following:

1) The hydrogen content is high, 660 litres of propane → 60 kg H_2 → 1,000 litres of H_2.
2) Small additions of freon allow for efficient γ-ray detection.
3) It is an analyser of proton polarization.

Let us consider the experiments in order of availability of liquids. Propane is immediately available, whereas deuterated propane presents some production difficulties.

N^{*++} production by $\bar{\nu}$

$$\nu + p \rightarrow N^{*++} + \mu^-$$
$$\hookrightarrow p + \pi^+ \ .$$

Events occurring on free protons would be recognized by momentum balance; any event unbalanced by more than two standard deviations from zero would be rejected. With this criterion it is estimated that only 10% of the events selected would occur in carbon. If 12% (by volume) of freon is added the background will increase to 16%.

The π-p invariant mass will indicate N^{*++} or S state production. In order to obtain good separation of the two processes, events above 1.5 GeV would be used and 100 events needed to settle the present outstanding questions of coupling constants and form factors.

It should be noted that any time-reversal violation will show up in the π and p angular distributions in the N^* centre of mass. With present conditions the expected rate is $\sim$ 0.5 events/day.

III. DEUTERATED PROPANE

The availability of free-neutron targets suggests immediately the study of the elastic form factors.

The events $\nu + n \rightarrow \mu^- + p$ would be selected by means of momentum balance and we estimate a 30% background due to events in carbon (effects of the deuterium fermi-momentum included). This background is, however, easily found experimentally from the ν run in propane.

This background effect is such as to decrease the statistical significance of the elastic events by about one-half. Thus, at least 200 events will be needed to improve on the present form-factor information.

Additional information can be obtained from the proton polarization concerning the form factors and time-reversal invariance, but $\sim$ 1,000 are needed.

In addition to the elastic events, all charge states of inelastic processes will be produced. The detection of a complex inelastic event from a free nucleon will prove somewhat difficult. However, a much clearer understanding of such processes will no doubt result. Thus, one can conclude with the following:

There is certainly much ν physics to be done with heavy liquid chambers, the only major difficulty is to increase the ν fluxes.