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A PROPOSAL TO STUDY NEUTRINO INTERACTIONS USING GARGAMELLE AT THE SPS

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I. INTRODUCTION

We express here our interest in two main lines of physics using Gargamelle in neutrino beams at the SPS.

a) A study of rare events (leptonic interactions, search for new particles), using the neutrino wide band beam at the maximum energy and at the maximum flux.

b) A study of neutral current interactions, and particularly the analysis of the (x,y) plot, using a narrow band beam with parents at 140 GeV (neutrino and antineutrino) $(x = \frac{q^2}{2m\nu}\ ,\ y = \frac{\nu}{E_\nu})$

This present choice results from two independent considerations :

1. The present trend of physics puts large emphasis on those new phenomena, new objects, such as neutral currents, charmed particles, leptonic interactions, violation of scaling...etc...

2. Gargamelle and the neutrino beams at the SPS have two specific properties which are important in the compar ison with FNAL :

a) the shorter shielding in the neutrino line (400 m in comparison with 1000 m at FNAL) gives a higher flux of neutrinos, particularly in the wide band beam, and also in the narrow band beam at intermediate energies.

b) the heavy liquid and the EMI separate hadrons and muons at a relatively lower momentum comparatively to the performances of other muon detectors (FNAL 15'EMI, BEBC EMI). Therefore, Gargamelle is a powerful instrument to study neutral current interactions, in which low momentum hadrons have to be identified.

II. THE PHYSICS SCOPE

A. The interest of the heavy liquid in the detection of leptonic interactions and of new particles associated with electrons has been already extensively demonstrated in many papers (1-2). The main points are :

- The study of $\nu_\mu + e^- \to \nu_\mu + e^-$
- The study of $\nu_\mu + Z \to \mu^- + e^+ + \nu_e + Z$

and the search for $W^\pm$.

- The detection of charmed particles.

- $\nu_\mu + e^- \to \nu_\mu + e^-$

The study of this process is an essential test of the leptonic neutral current interaction. The characteristic track of the electron in the heavy liquid, the determination of its charge and the clean visibility of the apex make possible an efficient search for this process in Gargamelle. The background coming from the reaction $\nu_e + n \to e^- + (p)$, in which the proton is not detected, is larger than in the antineutrino beam, but may be reduced to an acceptable level of 5% by applying a cut-off on the electron energy. The background coming from isolated rays is small because the probability that a ray be asymmetric at high energy is low. A radiation length between 25 and 40 cm would be desirable to separate electrons from gamma-rays.

- Multi-lepton search

Multi-lepton events are expected from many reactions and the reactions with an election will be easily identified in Gargamelle.

. the point-four-fermions with a scattering in a nuclear Coulomb field $\nu_\mu + Z \rightarrow \mu^- + e^+ + \nu_e + Z$.

. the production of the intermediate vector boson decaying into two leptons

$$\nu_\mu + Z \rightarrow \mu^- + W^+ + Z'$$
$$W^+ \rightarrow e^+ + \nu_e$$

. the production of charmed particles decaying into leptons (next chapter). Gargamelle is particularly well adapted to detect those rare process as with one emitted electron.

. The recent detection of dimuons events at FNAL in the IA experiment (3) is a good encouragement to look for similar events with $\mu^\pm e^\mp$ in Gargamelle. The associated hadronic shower will be studied.

- Charmed particles

This point appears today as a very promising one. An isolated charmed particle can be produced in a neutrino interaction through the reaction :

$$\nu_\mu + N \rightarrow \mu^- + C + \ldots .$$

The charmed particle is expected to decay mainly into a strange particle, associated with leptons or with hadrons :

where S is a hadronic system including a strange particle (Λ°, K°, K^-...), and ℓ is a lepton. Channel (1) would be easily identified with two leptons (μ^- and ℓ) in the final state. If $\ell = \mu$, it will be identified in the EMI. If $\ell = e$, it will be identified in the liquid.

Channel (2) will be identified by the invariant mass spectrum of $S^+(\pi)$, which is expected to be narrow.

B. The study of the structure functions in deep inelastic neutrino interactions induced by charged currents, has given fundamental information on the structure of the nucleon and on the structure of the weak interaction at high energy. This study will be pursued with more accuracy and with more details in the future ; the influence of the intermediate charged vector boson or of charmed particles could be detected. The counter experiment will give probably good results in this domain.

Similar studies are very interesting with interactions induced by neutral currents. The study of the cross-sections and of the structure functions in such processes gives informations different from those obtained in charged current reactions. Firstly, such a study is sensitive to the existence of the <u>neutral</u> intermediate Boson W°. Secondly, it is not sensitive to the production of charmed particles. Therefore it will be very important to compare the results from charged current and from neutral current processes.

In the absence of a significant deviation from scaling, the simple 3 valence-quark model and the Weinberg theory can be tested. The differential cross-sections on nucleon (50% proton, 50% neutron) are expected to be :

$$\frac{d^2\sigma_\nu^N}{dx\,dy} = \frac{3G^2 M E}{\pi}\; x g(x)\; \left(\frac{1}{2} - \sin^2\theta_W + \frac{5}{9}\sin^4\theta_W + \frac{5}{9}\sin^4\theta_W (1-y)^2\right)$$

where $g(x)$ is the quark x- distribution and θ_W the Weinberg angle. The detailed study of the (x,y) plot will be a precise test of this simple model and a good determination of the parameter $\sin^2\theta_W$. Of course other models can be tested.

The knowledge of the incident neutrino energy is essential to determine the parameters x and y of a neutral current interaction. In a charged current interaction, q^2 is mainly determined from the measurement of the visible trajectory of the lepton. In a neutral current interaction, q^2 has to be determined from the hadrons. This determination is very sensitive to the longitudinal component of the Fermi momentum of the target nucleon which introduces an important error on q^2, if the neutrino energy is unknown ($\Delta x \sim .20$).

The constraint introduced by the knowledge of the energy of the incident neutrino decreases this error by an order of magnitude, and the final errors on x and y will be comparable to those errors in the charged current events. It has to be noticed also that the measurement of all particles in the hadronic shower, giving a determination of the hadronic mass, is also a powerful constraint which also reduces the error coming from the Fermi-momentum. A detailed study on nuclear effects is on progress.

III.- BUBBLE CHAMBERS

Gargamelle with a mixture of freon-propane and BEBC with neon are, to the first order, two equivalent choices for the wide band experiment. The competition with hydrogen and deuterium experiments in BEBC makes probably possible that an experiment in Gargamelle should be completed earlier. The choice of the best liquid, a mixture of propane-freon will be decided later, taking into account the measurement and identification problems. The use of the light freon (C_2F_5Cl) could be envisaged because of its high density (1.2 g/cm^3) associated to a medium radiation length (25 cm).

To study neutral currents, Gargamelle appears

- The elimination of dense material in front of the chamber by a larger separation of the coils will give a clean experiment with a reduced neutron background.

- The "two planes" EMI of Gargamelle identifies hadrons at a lower momentum (1.5 GeV/c) than the BEBC EMI ($\sim$ 4 GeV/c), and therefore it is more efficient to isolate neutral currents events. About 80% of the NC events will be positively identified ; the necessary corrections to take into account the missing 20% will be small. A supplementary improvement of this efficiency (.7 GeV/c) can be obtained if an heavy slab of 3 interaction lengths is introduced inside Gargamelle in the last meter of the visible volume.

The liquid of the chamber will be a mixture of propane-freon to be determined more precisely later.

IV.- BEAMS

The number of events per picture in the wide band beam will not saturate the chamber, even at the maximum intensity of protons (1 or 2 events per picture). The high energy part of the spectrum appears today as equally interesting as the low energy part : new phenomena could arise at high energy, but low energy could provide more charmed particles. Therefore a beam optimised to give the maximum total number of events such as the one proposed by W.A. Venus and H.W. Wachsmuth (TCL 73-2) would be a priori a good choice.

The N5 beam, operated at 275 GeV for the counter experiment is not an optimised beam for the bubble chambers in two aspects :

1. The neutrino flux is small.

2. The proportions of ν_π (80 GeV) and ν_k (230 GeV) are of the same order of magnitude. The separation of ν_π and ν_k events (ν_k/ν_π events = .6) among the NC events is

The N5 beam can be used at a lower momentum and can be optimized to get the maximum flux (4.). The maximum number of events in Gargamelle is obtained with parents at 140 GeV (factor of 5 in comparaison with 275 GeV). The proportion of ν_k among ν_π is reduced to .18 in the number of events. The rate would be about 1 event every 20 pictures. The neutrino energy of 50 GeV will give hadronic showers probably still measurable with the classical techniques in a bubble chamber. Charmed particles can be produced up to a mass of 10 GeV.The (q^2, ν) plot can be explored up to $q^2 \sim 100\ (\mathrm{GeV}/c)^2$.

Reduced samples of pictures with parents at 60 GeV and at 275 GeV will be used to study the variation of the total cross section of neutral current reactions as a function of the energy. To increase the flux at 60 GeV up to an acceptable level, two larger aperture quadrupoles would be very useful.

V.- NUMBER OF PICTURES - COLLABORATION

The necessary number of neutrino pictures in the wide band beam will be about 10^6, because the interesting events will be rare (200 $\nu_\mu e^- \to \nu_\mu e$; $70 \nu_\mu Z \to \mu^- e^+ \nu_e Z$). A collaboration of 3 to 4 laboratories would be well suited to such a large experiment,

A good result on the neutral currents (q^2, ν) or (x,y) plot could be obtained with about 2000 events (a statistics comparable to the present one in charged current interactions); 200,000 pictures are necessary with neutrino and 400,000 pictures with antineutrinos at 140 GeV. 100,000 pictures at 275 and 60 GeV in neutrino would be necessary.

We feel that the formation of collaborations can be postponed to 1976 when a precise neutrino programme has been determined.

VI.- ANALYSIS POWER OF THE GROUP

6 physicists will be working full time on Gargamelle only. From now to 1977, two students will join this group. It has to be noticed that most of these physicists are from the CNRS and have not, or negligible, teaching charge.

Scanning and measuring tables - 10 tables are presently used to analyse the Gargamelle experiments. All the tables are equipped with coordinatographs, measuring in the image plane, on-line with a UNIVAC 418 computer. The tables will be equipped in the next future with a track-following device. These 10 tables will be devoted exclusively to Gargamelle. The BEBC pictures will be analysed in the same laboratory with independent equipments.

Computer : The Ecole Polytechnique group uses a 6600 CDC computer located at the Paris VI University.

Participation to the EMI : two physicists of the group are participating to the study of the Gargamelle EMI, and will continue to participate in the construction at CERN. A financial contribution from the laboratory to the EMI is under study.

VII.- CONCLUSION

The Ecole Polytechnique group intends to use Gargamelle at the SPS on, at least, two main lines :

- an experiment using the wide band beam (neutrino).
- an experiment using the narrow band beams in neutrino and antineutrino.

The choices of the liquids are strongly connected with the performances of the chamber, the measurement and identification problems. The final choices can be postponed to 1976.

The group wants to start both experiments as soon as possible. It would be very desirable to get two reduced samples of pictures as soon as the SPS and Gargamelle are in operation, in the beginning of 1977.

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