NEUTRAL CURRENTS IN GARGAMELLE

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Abstract : In this talk we present the latest status of the research of neutral currents in the wellknown Gargamelle bubble chamber, experiment which is still going on. The author has tried to collect the latest data from each one of the seven laboratories of the so called Gargamelle collaboration, and has done by himself some rough calculations. So the approximative numbers he gives for the leptonic neutral currents do not bind the collaboration.

Résumé : Nous présentons ici l'état le plus récent de la recherche de courants neutres dans la chambre à bulles bien connue Gargamelle, expérience qui continue encore. L'auteur a essayé de collecter les dernières données de chacun des sept laboratoires de la "Collaboration Gargamelle", et a effectué lui-même quelques calculs grossiers. Aussi les résultats approximatifs qu'il donne pour les courants neutres leptoniques n'engagent pas la collaboration.

I. THE EXPERIMENT

The two following reactions are studied

$$\begin{matrix} \nu_\mu \\ \text{or} \\ \bar{\nu}_\mu \end{matrix} + e^- \rightarrow \begin{matrix} \nu_\mu \\ \text{or} \\ \bar{\nu}_\mu \end{matrix} + e^- \qquad (1)$$

and

$$\begin{matrix} \nu_\mu \\ \text{or} \\ \bar{\nu}_\mu \end{matrix} + \text{Nucleon} \rightarrow \begin{matrix} \nu_\mu \\ \text{or} \\ \bar{\nu}_\mu \end{matrix} + \text{hadrons} \qquad (2)$$

referred at as "leptonic neutral currents" and "semi leptonic neutral currents" respectively.

The experiment is done in the Gargamelle heavy liquid bubble chamber filled with CF_3B_r (radiation length of 11 cm and collision length of some 60 cm). The dimensions of the chamber (a 4.8 m long and 1.8 m diameter cylinder) and the liquid used, ensure that most of the strong interacting particles interact in flight in the visible volume and are unambiguously identified as hadrons. Stopping protons are unambiguously identified too (as well as electrons).

The chamber is protected by the yoke (1.5 m), the coils (60 cm Cu) and the μ shielding (22 m Fe, upstream). The consequence is that any neutral hadron flux, reaching the chamber, must be severely attenuated and degraded before entering the visible volume.

The beam used is the Cern neutrino beam.

II. *SEARCH FOR "LEPTONIC NEUTRAL CURRENTS"*

The reactions

$$\begin{matrix} \nu_\mu \\ \text{or} \\ \bar{\nu}_\mu \end{matrix} + e^- \rightarrow \begin{matrix} \nu_\mu \\ \\ \bar{\nu}_\mu \end{matrix} + e^-$$

are forbidden to first order in the conventional weak interactions theory. In Weinberg's model their cross-sections are of the order of

$$\sigma \simeq 10^{-41}\,\text{cm}^2/\text{electron at 1 GeV}$$

depending on Weinberg's angle θ_w.

The "experimental topology" of such events is characterised by

- a single electron (negatively charged) originating in the liquid.
- no other correlated tracks (no hadrons, no gamma rays).
- a small angle with the axis of the beam.

This last point is imposed by kinematics which gives

$$\theta_{e\,\nu_{in}} \leqslant \sqrt{2m_e}\left(\frac{1}{Ee} - \frac{1}{E\nu}\right)^{1/2}$$

where m_e is the mass of the electron, E_e and E_ν the energies of the electron and the neutrino, $\theta_{e\nu_{in}}$ the angle between the incident neutrino and the outgoing electron ($\theta_{e\nu_{in}} \simeq 3.3°$ at $E_e \simeq 300$ MeV).

To get rid of low energy gammas and electrons we impose $E_e > 300$ MeV, which in turn guarantees $\theta_e < 5°$

1) Neutrino sample

375.000 pictures have been scanned trace.
No event was found.

2) Antineutrino sample

The analysis is not finished.

On the 4th of March 1974 approximately 1232000 pictures (non booster equivalent) are already scanned (50% of them scanned twice).

The scanning detection as computed from isolated gammas of a partial sample is bigger than 86%.

Two candidates were found with the following characteristics (fig. 1 and 2).

a- $E = 385 \pm 100$ MeV

$\theta_{e\nu} = 1.4° \begin{matrix} +1.6° \\ -1.4° \end{matrix}$

$x = 60$ cm (from beginning of the visible volume of the chamber).

$R = 16$ cm (distance from the axis)

b- $E = 412 \pm 133$ MeV

$\theta_{e\nu} = 2° \pm 2°$

$x = 260$ cm

$R = 39$ cm

Fig. 1

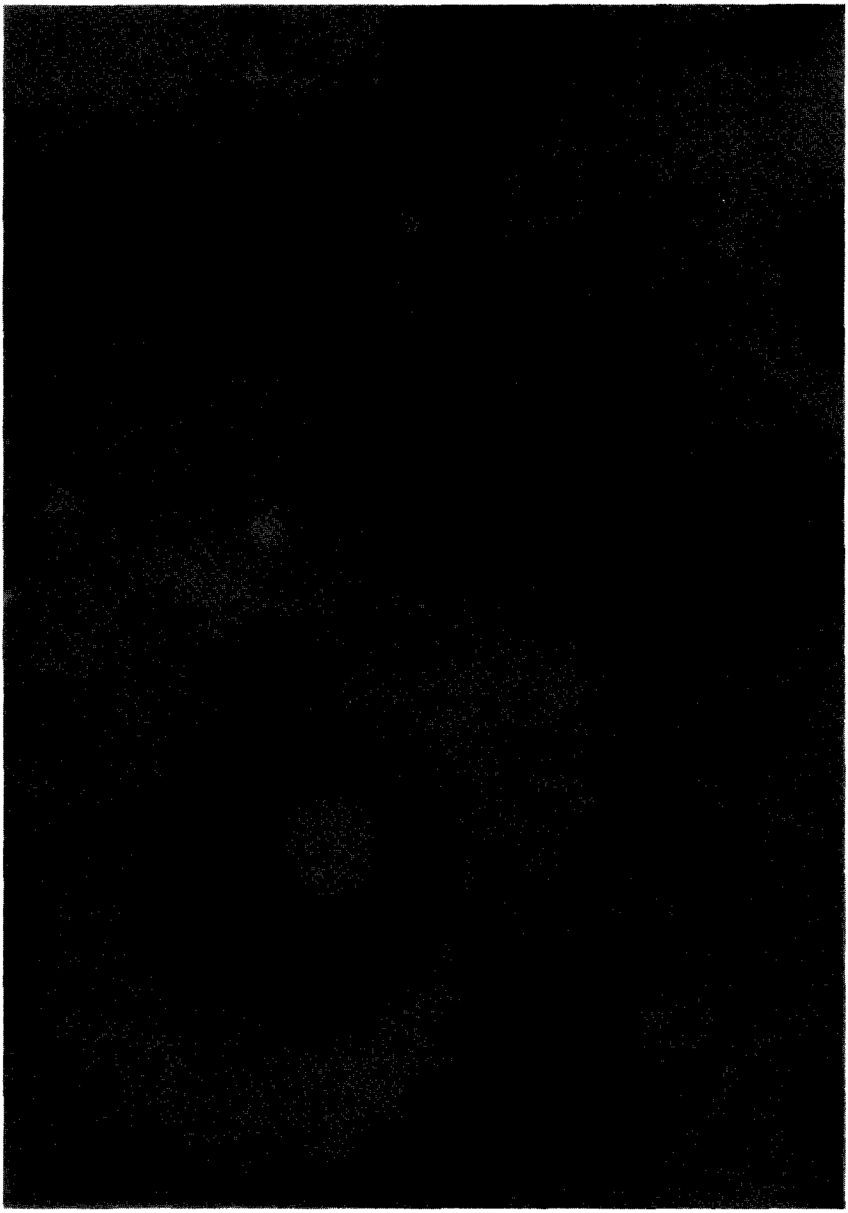

Fig. 2

3) <u>Background</u>

- The reaction $\nu_e + n \to e^-_{\theta<5°} + p$ where the proton of small energy is not seen is the main source of background. Its contribution is

0.3 ± 0.2 events in the ν sample
0.11 ± 0.07 events in the $\bar{\nu}$ sample

and has been determined from the study of

$$\nu_\mu + n \to \mu^-_{\theta<5°} + p \text{ not seen}$$

as well as from the ν_e flux.

- The other sources of background are :

- isolated γ's

- νe or $\bar{\nu} e$ $+ e^- \to$ ν_e or $\bar{\nu} e$ $+ e^-$

- $n + e^- \to n + e^-$

They all give negligible contributions.

4) <u>Results</u>

They are summarized in the following table :

	Flux ν/m^2	Expected number of events in Weinberg's model Min.	Max.	Background Number of events expected	Observed
ν	$1.8\ 10^{15}$	0.6	6.0	0.3 ± 0.2	0
$\bar{\nu}$	$4.2\ 10^{15}$	1.4	27.2	0.11 ± 0.07	2

90% confidence upper limits for the cross sections are :

$$\sigma_\nu \leqslant 0.26\ E_\nu\ (\text{GeV})\ \ 10^{-41}\ \text{cm}^2/\text{electron}$$

$$\sigma_{\bar{\nu}} \leqslant 0.35\ E_\nu\ (\text{GeV})\ \ 10^{-41}\ \text{cm}^2/\text{electron}$$

A maximum likelihood method combines ν and $\bar{\nu}$ results and gives

$$0.05 < \sin^2\theta < 0.5 \text{ at } 90\% \text{ C.L.}$$

The probability that the two observed $\bar{\nu}$ events are due to non neutral current background is 0.5%.

We would like to underline that these are not definitive results as the analysis is still going on and scanning efficiency and some background could change in the last samples (they have only been renormalized here).

III. SEMI LEPTONIC NEUTRAL CURRENTS

This is a study on energetic and inelastic interactions without any charged lepton in the final state.

A sample of 83000 ν pictures and 207000 $\bar{\nu}$ pictures has been used and a non negligible effect has been observed.

Events have been recorded in a reduced fiducial volume, 3.75 m long by 1 m diameter (that is 40% of the visible volume) in which the mean potential length is 170 cm (of the order of three interaction lengths for hadrons).

1) Events definition

We are interested in :

$$\begin{matrix} \nu_\mu \\ \text{or} \\ \bar{\nu}_\mu \end{matrix} + \text{Nucleon} \rightarrow \begin{matrix} \nu_\mu \\ \\ \bar{\nu}_\mu \end{matrix} + \text{Hadrons}$$

and we compare to

$$\left.\begin{matrix}\nu_\mu \\ \text{or} \\ \bar{\nu}_\mu\end{matrix}\right. + \text{Nucleon} \rightarrow \left.\begin{matrix}\mu^- \\ \\ \mu^+\end{matrix}\right. + \text{Hadrons}$$

the muon being defined in a very conservative way by :

- any particle satisfying one of the three criteria :
  - . leaving the chamber without interacting
  - . stopping and decaying (into electron)
  - . negative, absorbed after stopping(without any visible star).

We define the following 3 types of events : neutral current candidates (NC), charged current candidates (CC) and associated events (AS). (figures 3 and 4).

- NC Only hadrons. No other event in the same frame.
- CC Hadrons and one (and only one) μ candidate.
  The "hadronic part" is then identical to a NC configuration.
- AS "Normal" neutrino interaction and a star (with an individual vertes) which is identical to a NC configuration.

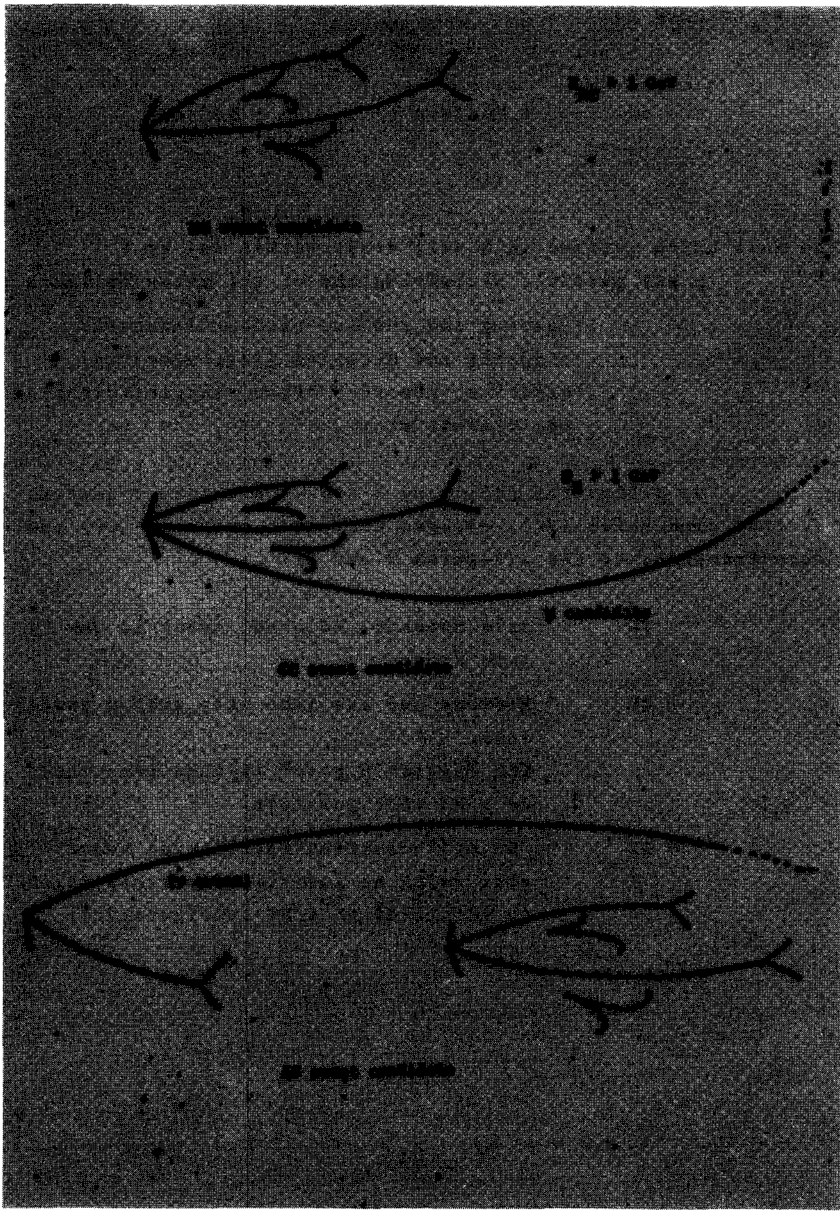

Fig.3

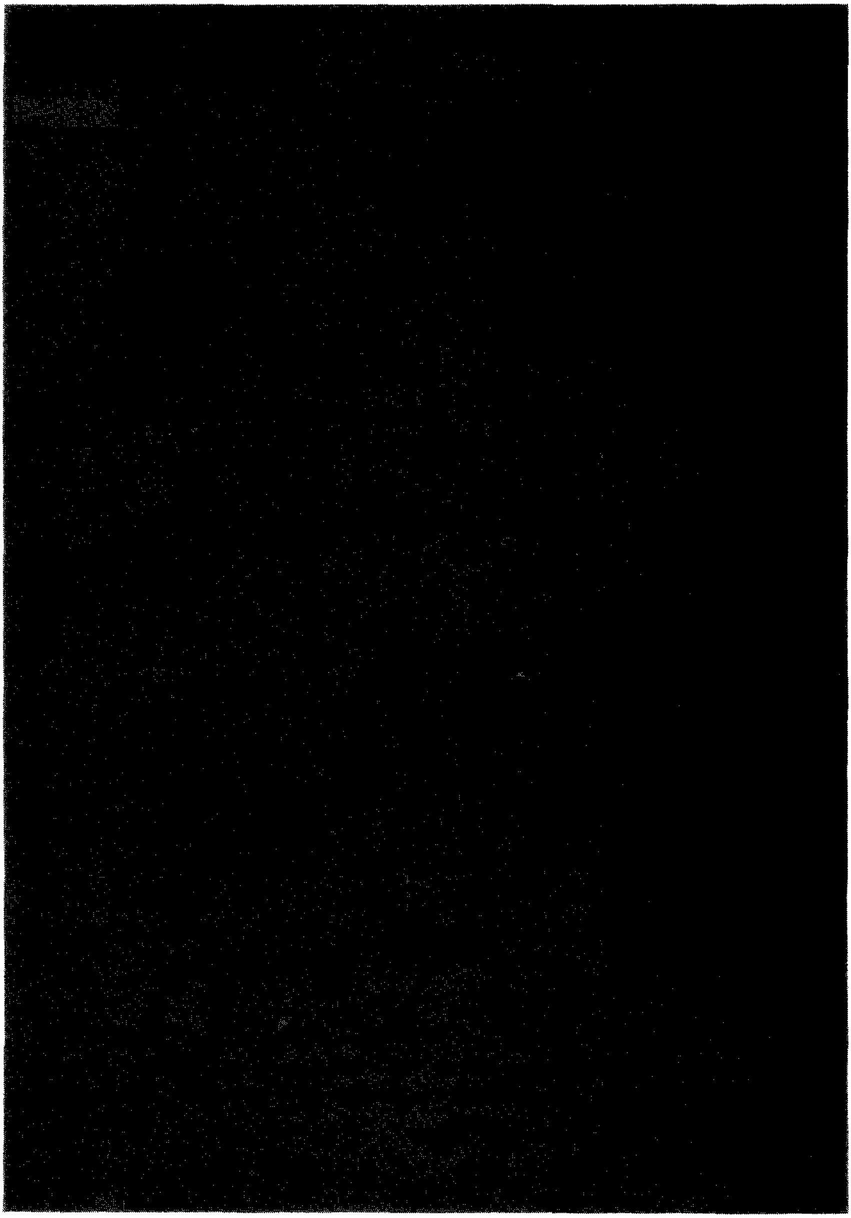

Fig. 4 - A typical neutral current candidate

In order to decrease background and to increase the precision of direction measurements we impose in any case :

$$E^{hadronic}_{visible} > 1 \text{ GeV for CC}$$

$$E^{total}_{visible} > 1 \text{ GeV for NC}$$

and for stars in AS

We are then left with the following number of events.

	ν	$\bar{\nu}$
NC	102	63
CC	428	148
AS	15	12
NC/pictures	1.2 10^{-3}	0.3 10^{-3}

2) Analysis

General characteristics of NC are similar (if not identical) to hadronic part of CC events. This is the case for spatial distributions, flatness of the distribution along the beam axis, energy spectrum, angular distributions.

3) Background : configurations simulating neutral currents

It has been shown that cosmic rays and interactions of neutral hadrons from the primary beam are quite negligible sources of background.

CC events with an invisible very low energy μ^- introduce a correction of 0 ± 5 events.

The main source of background comes from interactions of neutral hadrons produced by neutrino interactions outside the visible volume.

This background has been computed taking into account the environment of the chamber, the apparent collision length of neutrons, the angular distribution of neutrons emitted in neutrino interactions and their spectrum (these two last deduced from protons of neutrino interactions which must have a similar behaviour). All these ingredients lead to the ratio B/AS of background events (taken as neutral currents) relative to the associated observed events. We find

$$\frac{B}{AS} = 0.8 \pm 0.4$$

from which we deduce that the number of background events is 12 in the ν sample and 9.6 in the $\bar{\nu}$ sample (for details see ref. 3).

Correcting for the ν contamination in the $\bar{\nu}$ sample and for the probability for a neutral current to simulate a charged current event we find finally :

$$\left(\frac{NC}{CC}\right)_{\nu} = 0.23 \pm 0.03$$

$$\left(\frac{NC}{C}\right)_{\bar{\nu}} = 0.46 \pm 0.09$$

$0.3 < \sin^2\theta_W < 0.5$ (from Paschos and Wolfenstein's model)

at 90% confidence limit.

4) Conclusion

From the above ratios and their errors, we conclude that we are observing some kind of events which cannot be due to any kind of background and could be interpreted as neutral currents.

REFERENCES

(1) Gargamelle Collaboration. P.L. 46B1 (1973) 121

(2) Gargamelle Collaboration. P.L. 46B1 (1973) 138

(3) Gargamelle Collaboration. Observation of neutrino like interactions without muon or electron in the Gargamelle neutrino experiment. To be published in N.P.B.