CERN

CERN/SPSC/74-27
SPSC/M 22
1.3.1974

M E M O R A N D U M

THE LOCATION OF GARGAMELLE AND THE ELECTRONIC NEUTRINO EXPERIMENT IN THE WEST AREA NEUTRINO BEAM

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1. INTRODUCTION

For the purpose of this report the electronic experiment considered is of the form recommended by the SPSC in January 1974 (it will be called 'C'). The layout of this apparatus is indicated in figure 1 which was supplied by the electronic experiment collaboration; the maximum overall length is 38 m and the last element is an 18 m long high-density iron-core magnet.

Bubble chambers are inherently sensitive to background, in this case muons and neutrons, and this becomes an important consideration in choice of location. The location of the electronic experiment mainly affects beam intensity and energy (in the condition of covering the whole energy spectrum).

First we consider the possibility of placing the electronic experiment in front of BEBC, then two possible layouts for Gargamelle and the electronic experiment behind BEBC.

2. ELECTRONIC EXPERIMENT IN FRONT OF BEBC

(i) Muon Background in BEBC

Calculations performed by L. Pape indicate the following muon backgrounds in BEBC for a wide-band neutrino beam produced by 10^{13} protons at 400 GeV (i.e. at a beam intensity giving about 1 interaction per 2 pictures in BEBC visible volume, filled with hydrogen).

Muons/pulse (wide-band beam)

Source of Muons	Visible in BEBC
BEBC Magnet and Shield	13
Neutrino Shielding (mainly end of earth at about 50m)	27
Electronic expt. ending at 18 m in front of BEBC	100

The presence of a massive electronic experiment so close in front of BEBC makes a significant increase in the visible muon background, to a level which is undesirable.

(ii) Building Alterations Required

In order to accommodate a neutrino counter experiment of the type considered in front of BEBC, considerable modifications to the existing building E2 would be needed. Building E2 is the small hall linking the main West Hall building (E1) with the BEBC building.

The centre line of the neutrino beam emerges from the floor level of hall E2 about 50 m upstream of BEBC and at that point is just crossing the north wall of the West Hall (E1). After a further 3 m the neutrino beam line passes into hall E2.

If we exclude the demolition of the north wall of E1 and we respect the safety regulations by staying more than 12 m in front of BEBC, then the only possiblity to accommodate a counter neutrino experiment is in hall E2, which is 35 m long. In order to allow proper access to a counter neutrino experiment of about 4 m diameter, at least 2½ m radius all around the beam wou need to be excavated. This space on the north side of the neutrino line is occupied by the foundations of the north wall of E2 and the wall itself and hence this wall would need to be displaced by about 3 m.

Such a building alteration is complicated by the continuing need for the existing crane in E2 which at the moment serves the R.F. beam to BEBC and will later also be needed for the installation of counter experiments which at 200 GeV will extend into E2. A preliminary study of how this might be achieved has led to the view that it would require:

a) installation of pillars to support the roof of E2
b) the provision of a temporary wall down the middle of E2
c) the removal of the crane
d) the demolition of the north wall and its foundations and half of the roof of E2
e) the excavation of a pit about 5 m wide sloping upwards and having a depth of about 2½ m at the beginning of hall E2 and a depth of about 1 m at the end of hall E2

f) reconstruction of a new wall 3 m further north, together with a new roof

g) installation of two new cranes, one serving the area of the counter experiment and one serving the other half of E1, which are separated by the roof-supporting pillars.

(iii) Hadron Calibration

Counter neutrino experiments contain hadron shower calorimeters which require calibration for maximum usefulness. With a counter installation in front of BEBC it seems extremely difficult to provide a high energy hadron beam for calibration purposes.

(iv) Space Available

Given the complications outlined in 2 (ii) it is not possible to provide in front of BEBC more than about 30 m of effective longitudinal space for a counter experiment.

Conclusion

Since the counter experiment discussed may extend to $\sim$40 m, the location in front of BEBC is unsuitable. If this were not so then the background induced in BEBC would become the major factor; any future proposal to place material in front of BEBC should satisfy the requirement that it does not lead to a significant increase in background in BEBC above the level due to the BEBC magnet and shielding.

3. LOCATIONS BEHIND BEBC

Two solutions have been considered (figure 1). In I the electronic experiment (C) follows BEBC with Gargamelle placed beyond at about 120 m behind BEBC; in solution II, the relative positions are reversed. The distances between BEBC and C in I, and between BEBC and Gargamelle, Gargamelle and C in II are determined mainly by safety requirements.

First we review sources of background for Gargamelle and the dependence of background levels on location. Then we consider the effect of location on C.

3. (i) GARGAMELLE BACKGROUNDS

(a) Muon:

The muon background is generated by the neutrino beam in material upstream from Gargamelle and also in matter local to Gargamelle (magnet coils, etc.).

The locally produced muon background has not been calculated but is estimated to be ≤ 5 per picture.

Calculations have been made for muons originating in upstream shielding or equivalent massive apparatus. The results are given for three values of 'd', the distance from centre of Gargamelle to the end of the dense material.

d (meters)	Muons/picture (wide-band beam)
56	5
25	40
15	120

Note: These figures are estimated for wide-band neutrino beam, 400 GeV 10^{13} protons interacting; the background during narrow-band beam operation will be negligible.

(b) Neutron Background

This is very difficult to estimate but is particularly important for experiments on hadronic neutral currents. An attempt has been made to estimate the background by scaling from the present conditions at the PS. Again one must consider the relative importance of local (Gargamelle and its surroundings) and remote (upstream) sources.

The measure of neutron background chosen by the Gargamelle group is the ratio of neutron-induced background to the number of hadronic neutral current events (i.e. background/signal). In its present location and at 26 GeV this ratio is estimated to be about 20% when a cut-off in visible hadron energy $E_h \gg 1$ GeV is applied. The 20% (background/signal) has been estimated to come from the following sources:

Source of neutrons	B/S (at 26 GeV)
GGM Magnet	9%
Beam entrance	3%
Magnet coils	5%
Shielding	3%
Total B/S	about 20%

The neutrons generated in the GGM magnet enter the visible volume from the sides of the chamber. If we scale the E_h cut-off proportionally to the incident proton energy then, owing to the increasing forward collimation of the hadrons as the neutrino energy is increased, the background entering from the sides will become less important. For a neutrino beam generated by 400 GeV protons, this effect has been estimated (Rousset - SPSC/M 15) to reduce the background from the magnet by a factor of 15; in the following we assume a reduction by a factor 10.

The neutrons generated in the chamber window at present energies contribute 3% to the background/signal. At higher energies, again assuming a scaled cut-off ($E_h \geqslant 16$ GeV at 400 GeV), the larger multiplicity of hadrons produced by the interaction in the window will enable some of the neutron background from this source to be eliminated because accompanying hadrons will be visible in the chamber. We will assume that this reduces the contribution by a factor 3.

Another important local source of neutrons are the magnet coils which partially cover the entrance face of the chamber. It is possible to reduce this source if new coils are fitted or if the present coils are tilted so as to provide a wider entrance aperture. We will assume that either of these actions produces a reduction by a factor of five.

The remaining sources of neutrons are those external to the chamber in the form of massive objects located some distance d metres in front of the chamber. The Gargamelle group have made estimates of the dependence of such externally produced neutron background on the distance d, again assuming a scaled cut-off in E_h. The effect of increasing d depends on the energy of the neutrinos so for this purpose the spectrum has been divided into two regions. The results are given relative to the background with d=0 (i.e. the present situation).
In brackets are the corresponding B/S ratios from this source.

d	0 m	15 m	25 m	$\geqslant$50 m
$E_\nu < 40$ GeV	1 (3.5%)	1/5 (0.7%)	1/8 (0.5%)	1/80 ($\sim$0%)
$E_\nu > 40$ GeV	1 (3.5%)	1/2 (1.8%)	1/3 (1.2%)	1/8 (0.5%)

We can now estimate the neutron background from various sources at 400 GeV assuming the cut-off of $E_h \geqslant 16$ GeV.

Source of neutrons	B/S (at 400 GeV)	
GGM Magnet	0.9%	
Beam entrance	1.0%	
Magnet coils	1.0%	(5% if coils not moved)
Total fixed local sources	2.9%	
External sources	2.5%	(d=15m)
	1.7%	(d=25m)
	0.5%	(d$\geqslant$50m)

Comments: 1. If the coils are not moved they determine the major part of the neutron background, independent of external sources.

2. If the coils are moved then the sides and front of the chamber body, etc. become the dominant factor, provided the external source is at a distance exceeding $\sim$25 m.

3. Although the background percentages are smaller than in the present experiment:

   (a) there are large uncertainties in the estimates;
   (b) these figures apply for a cut-off at 16 GeV and the background will become larger if this limit is reduced.

4. Another source not mentioned so far is the blast-wall needed in front of Gargamelle. It seems possible to replace concrete with aluminium over a 3 metre diameter on the beam axis, this will have a small effect.

5. In the two locations considered, the distances from centre of Gargamelle to end face of up-stream neutron sources are:

   I Distance to end of C $\geqslant$ 40m
   II Distance to exit of BEBC EMI $\sim$ 56m

6. The question of neutron background is raised in the context of a hadronic neutral-current experiment. The comparison is made with a low energy, wide-band beam experiment; however, the significance of the background may be altered if one considers a narrow-band experiment in which - to achieve some information on E - the analysis is confined to events with $E_h > E_\nu(\pi)$ $\frac{1}{2}E_\nu$ (K).

7. The muon background could be reduced by energising the iron-core magnet spectrometer to deflect the muons away from the beam axis.

8. The Gargamelle group would accept a distance d $\nless$ 40m.

3. (ii) ELECTRONIC EXPERIMENT POSITION

The electronic experiment, C, asks for narrow-band beam conditions which allow E to be determined from measurements of radial position of the interaction vertex and such that the full and continuous spectrum of E_ν (from π decay and K-decay) is within the useful radius of their hadron shower detector. As the distance of the experiment from the effective neutrino source is increased there is a reduction in flux. This reduction depends on the criteria chosen for running conditions in the narrow band beam and can be 20% for neutrinos if position II is chosen rather than I. For the wide band beam the effect is a reduction of solid angle by 17%; there would be a similar reduction for Gargamelle.

3. (iii) OTHER FACTORS

a) Safety

A preliminary study (Pietersen) failed to reveal any major difficulties with one solution rather than the other; both are acceptable provided appropriate precautions are taken. The next step would be formal consideration of a detailed layout by the Safety Committee.

b) Costs

It is not possible at the present time to give detailed cost estimates for the installations discussed. However, to first approximation the total cost of installation of both Gargamelle and a counter experiment is independant of the relative locations. At a more detailed level, the rising beam implies that the equipment installed furthest downstream must be supported higher in the air and this may be more costly for Gargamelle, which must sustain the dynamic load of the counter experiment. On the other hand, the need of the counter experiment for hydrogen and deuterium targets might imply more costly transfer lines from the BEBC storage area if these experiments are located further downstream from BEBC.

We conclude that cost cannot be considered a determining factor in the decision on the relative locations of the two installations.

c) Test Beam

Studies are under way to design a test beam of charged hadrons which could be used to calibrate the calorimeter of the counter experiment or to test GGM with charged particles. Solutions seem possible whichever choice of location is made and no clear advantage either way emerges from this consideration.

4. CONCLUSION

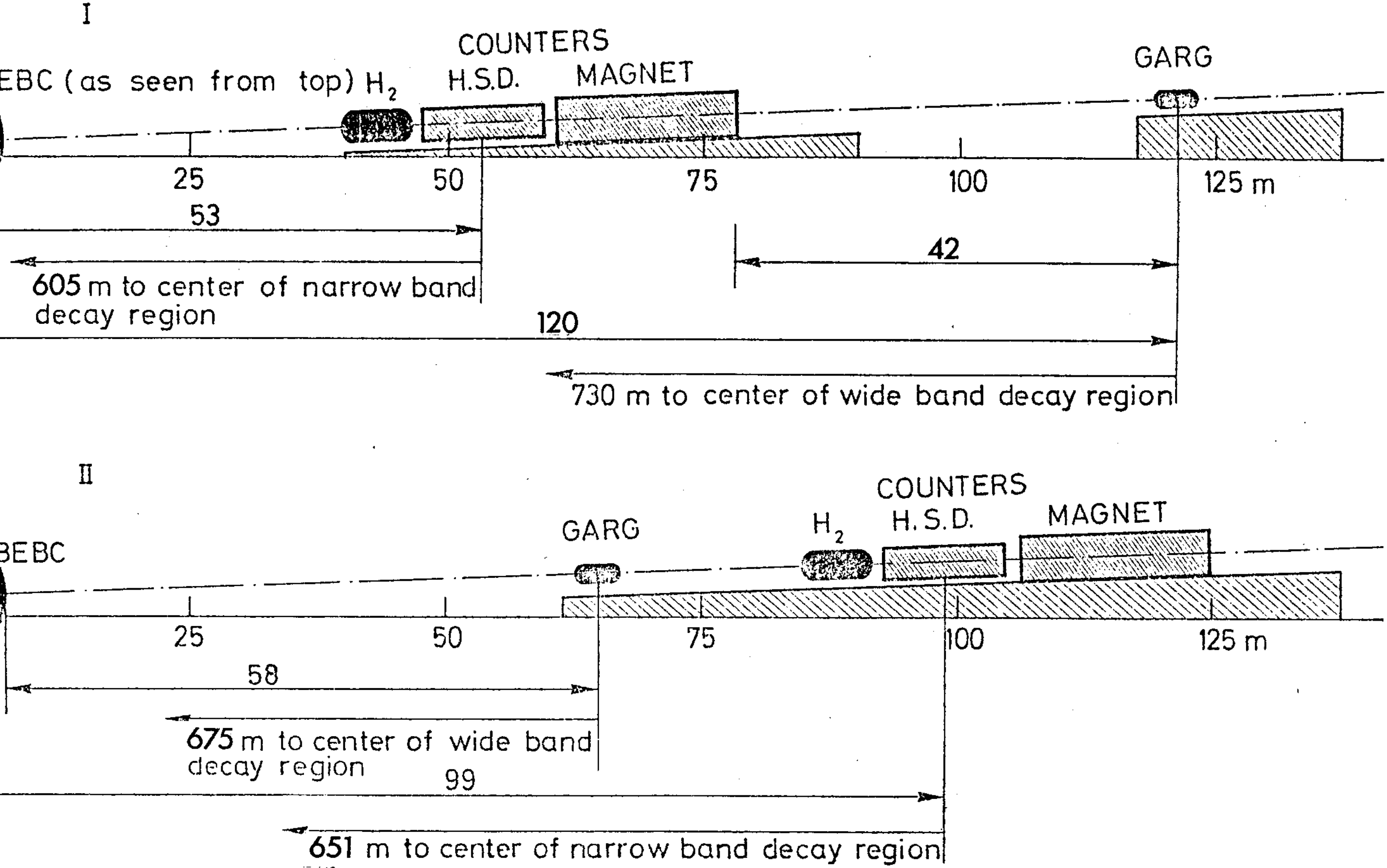
There do not appear to be any major reasons of physics to favour one solution rather than the other provided that if solution I is chosen then

(i) In view of the uncertainties inherent in the background estimation, a space not less than 40m in front of Gargamelle should be guaranteed free of dense material during a future Gargamelle experimental programme. This restriction may be reviewed in the light of operating experience in the West Area.

(ii) During wide-band operation the iron-core spectrometer magnet should be energised to de-focus negative muons if necessary.

The counter experiment considered here can satisfy these provisions if solution I is chosen, <u>however</u>, provision (i) would exclude the placing of a second massive neutrino experiment between C and Gargamelle; this would then have to go behind Gargamelle; however, in this position it would be no further from the neutrino "source" than if it was placed behind C in solution II.

For either solution the exact positions are subject to safety and engineering requirements which depend on a detailed study of the site.


I
COUNTERS
EBC (as seen from top) H_2
H.S.D.
MAGNET
GARG
25
50
75
100
125 m
53
42
605 m to center of narrow band decay region
120
730 m to center of wide band decay region
II
BEBC
GARG
H_2
COUNTERS
H. S. D.
MAGNET
25
50
75
100
125 m
58
675 m to center of wide band decay region
99
651 m to center of narrow band decay region