THE "GARGAMELLE" PROJECT

A. Lagarrigue,
Ecole Polytechnique et Orsay
Paris.

I shall describe the proposed construction of a very large propane chamber. This is a joint project of the Ecole Polytechnique, French Atomic Energy Commission, the University of Paris-Orsay and CERN.

I. MEASUREMENTS IN THE CHAMBER

The parameters of the chamber are the following: the chamber is a cylinder of length 4.5 m and diameter = 1.92 m. The fiducial volume lies between 10 and 11 cubic metres. The average magnetic field of horizontal direction is 21 kG with 6 MW. The chamber can be filled with all mixtures from pure freon(CF_3Br, d = 1.5 X_0 = 11 cm) to propane (C_3H_8, d = 0.4, X_0 = 120 cm). The chamber is movable. The advantage of such a chamber is twofold: firstly, much more information is provided by each event, and secondly, the number of events is obviously largely increased.

These two improvements are especially interesting for neutrino physics. Let us examine the first point.

1. Accuracy in momentum measurement

The relative accuracy is given by the formula

$$\frac{\Delta P}{P} \sim \frac{1}{B(X_0 \cdot L)^{1/2}} ,$$

where B is the magnetic field, X_0 the radiation length (80 cm in most of the experiments). L is the length of measurement.

For a given detection probability of γ rays, it clearly appears from this formula that the accuracy varies as 1/L. In other words, in a heavy liquid bubble chamber, the accuracy is inversely proportional to the dimensions of the chamber. This is not quite true for very large chambers since it is limited by the interaction length, which is of the order of 1.5 m. The expected accuracy for $\Delta P/P$ is around 3% and for angles around 0.1°.

2. Detection efficiency of γ's and accuracy of the measurement

With such large dimensions and a radiation length around 80 cm, the detection efficiency is very close to one. We have computed the accuracy in γ measurement, using our experience of such measurements. Average values are as follows:

	electron	γ	π^0
$\frac{\Delta P}{P}$	12.5%	9%	6.5% .

3. High stopping power

A large number of particles stop in the chamber and can be identified.

4. Identification through interactions and decay

This is one of the main advantages of such a large chamber. It is particularly useful for neutrino experiments in order to distinguish between π and μ. The interactions can also be used for identification of fast strange particles or non-decaying K_2^0. The neutron detection is also greatly enhanced.

5. Better identification by δ-ray signatures

This method was explained yesterday morning by Agnès Lecourtois. In this chamber the distinction between π and protons can be achieved with a reasonable probability (more than 30%) up to 4 GeV/c.

6. Polarization analysis achievable on a bigger scale

For stopping muons, the angular distribution of the decay electron will allow an estimate of the initial polarization. In addition the presence of carbon provides an excellent analyser for polarization of nucleons.

All these properties clearly show how much additional information is associated with each event.

II. PHYSICS WITH THIS CHAMBER

Many types of experiments can be carried out with such a chamber. Neutrino experiments are one of these. Others are :

1) Jet experiments with or without a hydrogen target inside the chamber.

2) High-energy muon experiments, mainly for inelastic events.

3) Medium-energy experiments. If we compare this chamber with our present chamber, we can expect a factor 400 in the number of completely analysed Ξ^0 events, 20 for Ω^- and so on.

4) We can also imagine setting up inside the chamber the intersection of the two 25 GeV proton beams if the collision rings are built.

Let us say a few words about the neutrino experiments.

We have seen the advantageous effect of a larger chamber on the quality of each event. Let us now consider the number of events. The fiducial volume of the chamber is 10 m^3, which has to be compared with the fiducial volume of the old CERN chamber in the last experiments, namely 220 litres.

This factor 45 can be fully used for the low-energy part of the neutrino spectrum (roughly speaking). For the higher part, the gain is certainly less because of the size of the beam, but we can take advantage of it by increasing the π decay length. Yesterday, we heard some previsions about the increase of the flux intensity at the PS. With respect to the present situation, we can reasonably expect an order of magnitude.

On the other hand, some improvements are also expected from the magnetic horn and the shielding, if they are adapted to the energy range required in specific neutrino physics. By combining all these factors, a gain between 500 and 1,000 appears quite reasonable. Under these conditions the total number of events per day is around 10,000.

What seems to us extremely important is the following: the number of ν events per day with this chamber is quite comparable to the number of events for strong interactions in present bubble chamber experiments. In other words, five years from now we can expect to be in the same position with ν beams for weak interactions as we are now with proton beams for strong interactions and electron beams for electromagnetic interactions.

Two types of run can be envisaged. The first is with pure freon CF_3Br with high-energy neutrinos. These conditions are suitable for rare events and, more generally, for all kinds of events where it is not essential to interact on a free proton : generally, the study of the leptonic vertex (for instance, such as the time-revorsal violation experiment where the muon polarization is studied).

We can expect to see about one event per day from the intermediate boson if the mass is 3 GeV, and to see a few events per day from the reaction

$$\nu_e + e^- \rightarrow e^- + \nu_e \; .$$

The second type of experiment has to be performed in propane with a small amount of freon to optimize the radiation length. The physics has been discussed yesterday by Cundy and Block. The size of this chamber will make this type of physics very exciting.

III. TECHNICAL ASPECTS OF THE CHAMBER

Let us say a few words now about the chamber itself.

The first slide shows a general view of the chamber, which is a cylinder 4.50 m long and 1.90 m in diameter. The coils are vertical and the magnetic field horizontal. They are close to the median plane, thus providing 21 kG at the centre, at reasonable cost.

Expansion takes place through a pole by means of four longitudinal membranes inside the chamber. Illumination uses the Scotchlite technique and the wide angle cameras are located on the same side as the expansion.

Slide 2 shows vertical and horizontal sections of the chamber, exhibiting the special shape of the chamber ends.

Slide 3 shows a vertical section of the chamber body and a view of the body on the expansion side. The expansion principle is shown here, with its numerous Grove valves used for recompression, as well as for expansion. For protection against misfunctioning of some of the valves, their number is intentionally larger than necessary.

Slide 4 shows the illumination principle.

Several versions are considered:

a) As shown eight cameras are located among the membranes, and the photography is direct (Fig. 2a).

b) The disposition is the same but the photography takes place through a glass window, floated between propane and oil, according to the system in use at Berkeley in the W. Powell chamber. This system might appear desirable in case of boiling at the surface of the membranes (Fig. 2b).

c) The floating window is replaced by a floating mirror and the photography is taken from the opposite side by means of five cameras only (Fig. 2c). The advantage of this solution is self-evident: the angular aperture required is smaller, and the optical conditions are improved. However, the tracks appear double and the spurious out-of-focus images can be a nuisance in the case of large flux experiments (such as muon experiments). We think that the chamber can easily be built for an alternate use of the above-mentioned solutions, according to experimental needs. The film size is 50 mm in the eight camera setup and 70 mm in the five camera solution. The depth of focus is 1.60 m.

Slide 5 shows a possible type of objective. To the left, a protective window is shown with a special internal parabolic shape, which will transform a 110° aperture in the chamber into a 90° aperture for the objective. Conventional optics are thus obtained, which allow for easy image transport outside the magnet where the cameras are located. However, the parabolical window must be changed when the refractive index of the liquid is changed. Another approach is to use a spherical window centred at the objective. This solution is index independent but makes use of 110° objectives for which the image transport is more difficult.

Slide 6 shows the track width as a function of the depth in the chamber when the opening of the diaphragm is varied.

The chamber project was studied in collaboration with the engineers of the Saturne Division at the Atomic Energy Commission, Saclay. The estimated cost is three million dollars. The price comprises all the hardware including compressors, manufacturing, construction and testing. It does not include the necessary 6 MW generator and the various facilities at CERN. The extra cost there would be 700,000 dollars.

Green lights for the beginning of the construction are expected soon. A three years' delay is necessary for construction, installation and tests. The first experiments could be done in the second half of 1968.

FIGURE CAPTIONS

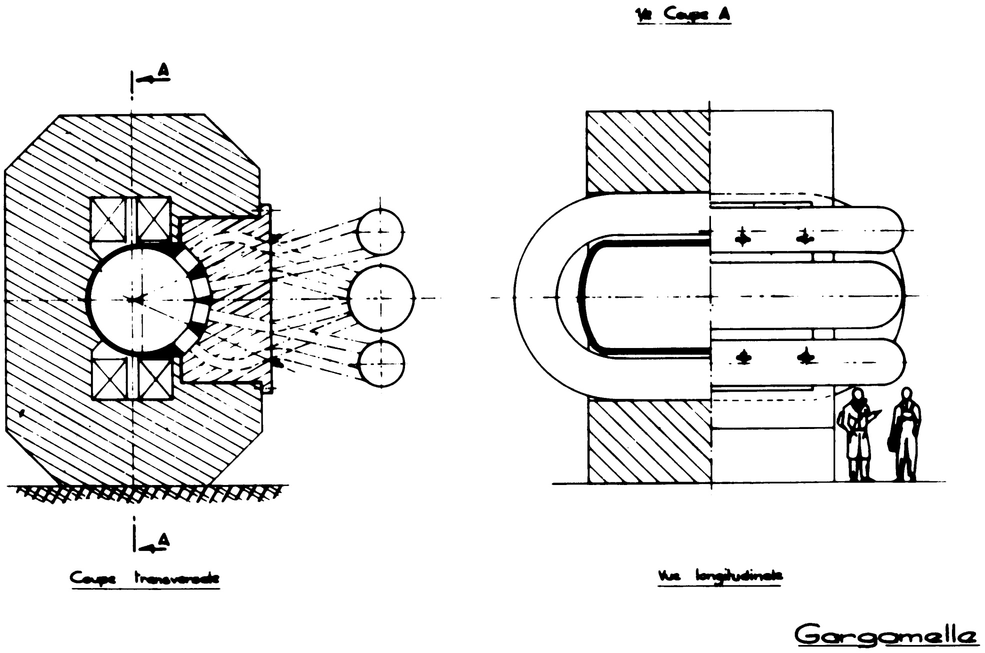
1/2 Coupe A
A
A
Coupe transversale
Vue longitudinale
Gargamelle

Fig. 1

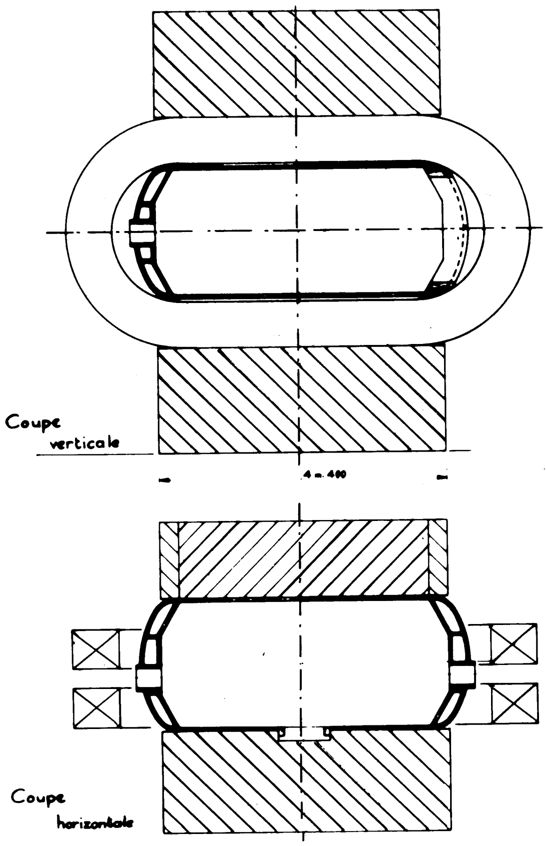
Coupe verticale
4 m 400
Coupe horizontale

Fig. 2

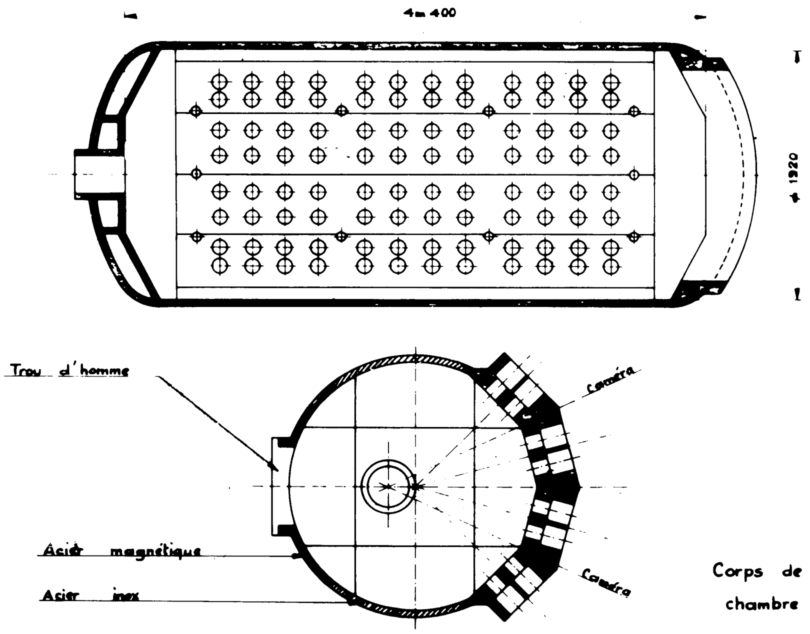
4m 400
ϕ 1920
Trou d'homme
Acier magnétique
Acier inox
caméra
Caméra
Corps de
chambre

Fig. 3

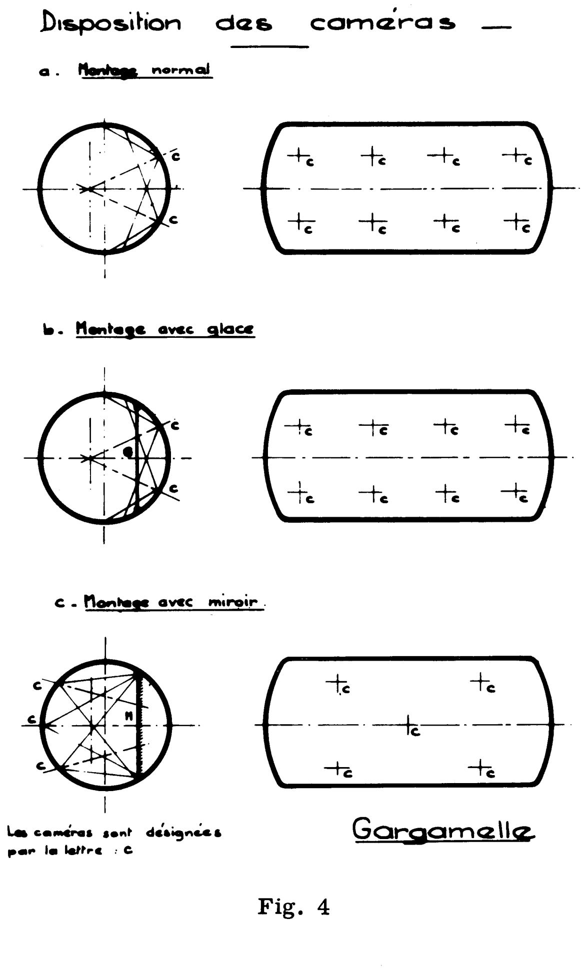
Disposition des caméras —
a. Montage normal
b. Montage avec glace
c. Montage avec miroir
Les caméras sont désignées
par la lettre : c
Gargamelle

Fig. 4

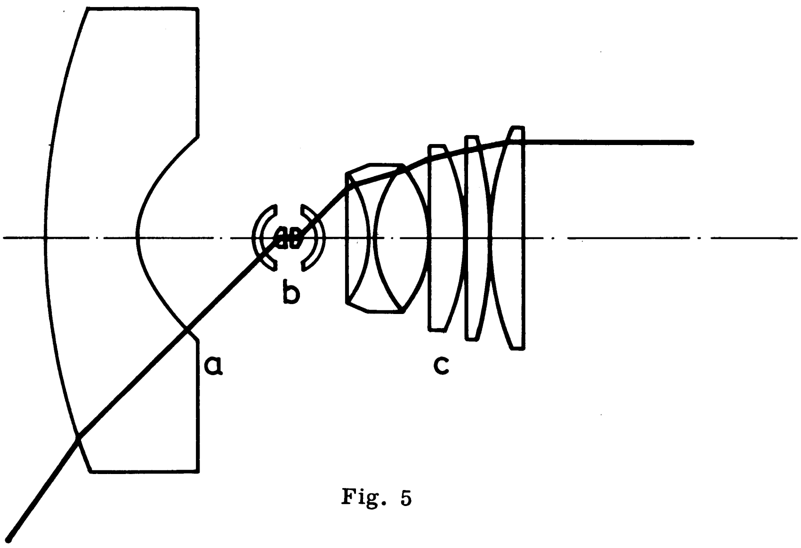
a
b
c

Fig. 5

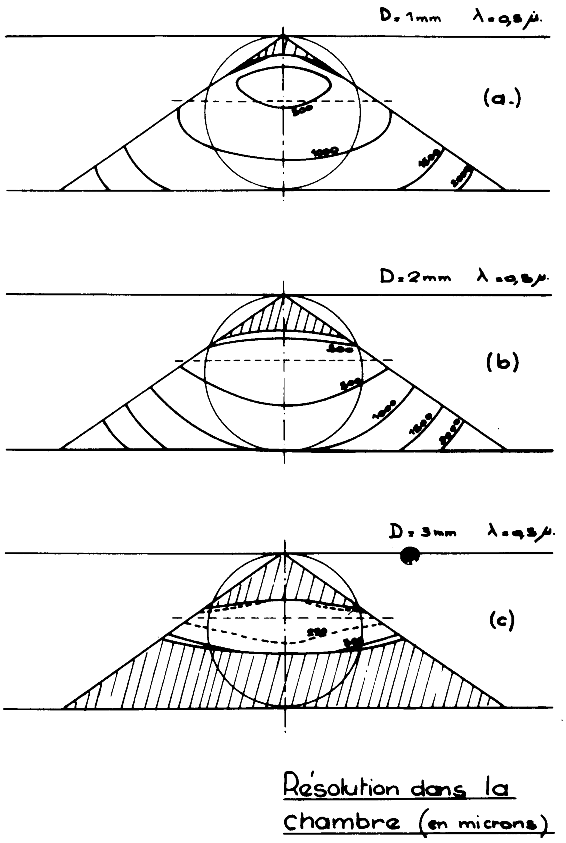
D = 1mm λ = 0,5 μ
(a.)
D = 2mm λ = 0,5 μ
(b)
D = 3mm λ = 0,5 μ
(c)
Résolution dans la
chambre (en microns)

Fig. 6