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DISCUSSION

ROSENFELD: You state that you do not get as good location accuracy with a larger chamber and larger radiation length, but actually, of course, just position accuracy is not the whole story. If you want to analyze an event you also want to take advantage of the fact that you measure the momentum of these pairs after you see them and then presumably fit them. And in a larger chamber you can presumably measure their momentum more accurately, so I would think this would

tend to make the propane chamber compete rather favourably. Now, is this true?

POWELL: I agree completely with that. I presented a one-sided argument. If you also measure the momentum, I am sure that you get a much better result with a large chamber and you certainly have more on the dynamics. I think, however, it still is true that you do not locate a point any better.

PROPANE AND HEAVY LIQUIDS BUBBLE CHAMBERS AT THE ECOLE POLYTECHNIQUE, PARIS

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(presented by A. Lagarrigue)

After the construction of a small experimental bubble chamber in 1957, the Ecole Polytechnique Group built a 20 liter chamber, which has been recently operated in connection with the Saclay synchrotron. Construction of a larger chamber ($100 \times 50 \times 50 \text{ cm}^3$) is nearly completed. This chamber will be operated in a 20 kG magnetic field.

THE 20 LITER CHAMBER

General characteristics

The chamber is rectangular in shape and its useful dimensions are: length 34 cm, width 20 cm and depth 24 cm (see Figure 1).

It was designed for operation with a mixture of 50% methyl-iodide and 50% propane by volume as suggested by I. Pless (MIT). This mixture combines the advantages of a short radiation length (10 cm) and of a concentration in hydrogen which is 80% of that of liquid hydrogen. On the other hand, methyl-iodide is highly corrosive and somewhat toxic. Moreover, the mixture has to be heated to at least 115°C for correct operation in our chamber. A chamber which can withstand these severe conditions can be operated without modification with a number of heavy liquids used in bubble chamber techniques, such as propane, freons, etc.

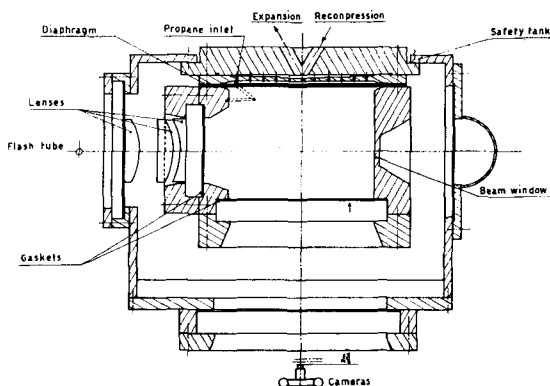


Fig. 1 Schematic drawing of the 20 liter bubble chamber.

The chamber is made of forged stainless steel.

Its main features are side illumination and back expansion. The reasons we chose side illumination are :

- 1) Undesirable reflections and diffusions are easier to suppress with that technique than with back illumination.
- 2) Back expansion is made possible. This has the advantage of reducing the displacement of the membrane since the expansion occurs on the side of the chamber which has the largest area.
- 3) Should the chamber be placed in a magnetic field, the side location of the flash tubes allows the use of a back pole piece.

Illumination is provided by a 22 cm long xenon flash tube. The power required is no more than 60 J. The light is focused by means of a lens system and enters the chamber through a 35 mm thick side window.

Temperature and chemical attack were the main technological difficulties encountered in the design of the chamber. The synthetic rubber called "Viton A",(*) which keeps its elastic properties at high temperature and is not attacked by methyl-iodide, has solved our gasketing problems. Since it became available to us only during the course of our experiment, gaskets made of coated rubber protected by a U-shaped annealed copper trough have been tried out successfully.

Several types of diaphragm have been tried out in the course of the experiment. The latest one was made of a "Viton A" frame 0.4 mm thick followed by a sheet of "Mylar" 50 μ thick, a sheet of dacron coated Viton 0.25 mm thick which provided a black background, a sheet of Mylar 0.2 mm thick for mechanical strength and finally a sheet of coated Fairprene(*) No. 5784, 1.26 mm thick. This type of diaphragm was found to be very satisfactory.

Three cameras which have lenses with focal length 180 mm and demagnification 1/10 are located about 2 meter in front of the 50 mm thick tempered glass main window. One of them is placed approximately on the chamber axis, the two others are located 30 cm above and below.

The chamber is completely surrounded by a welded steel safety tank in which windows are provided for illumination and photography. The particles enter the chamber through a 10 mm thick beam window 80 mm in diameter.

Operation of the 20 liter chamber at Saclay

A run of 120 000 pictures has been completed in June using a 1 GeV π^- beam extracted from the 3 GeV proton synchrotron "Saturne". The main purpose of the experiment was to take advantage of a chamber which is a good γ ray detector to study the neutral decay modes of strange particles.

The chamber and its auxiliary equipment were placed inside a heavy concrete block-house with 1 meter walls and a 60 cm roof. The side of the block-house opposite to the machine was left open. With this shielding condition it was found that the background in the chamber, which consisted mainly of slow electrons, was kept to a reasonable but not negligible level for the 10^9 protons per pulse machine intensity required for our experiment.

It was found that because of side illumination, the tracks produced in the chamber could be seen very clearly with the naked eye. For this reason the timing sequence for the operations of the chamber, expansion, triggering of the flash, recompression, along with temperature and pressure conditions could be set easily. The excellent visibility of the tracks was very helpful, especially since operations

(*) Made by the Dupont de Nemours Company.

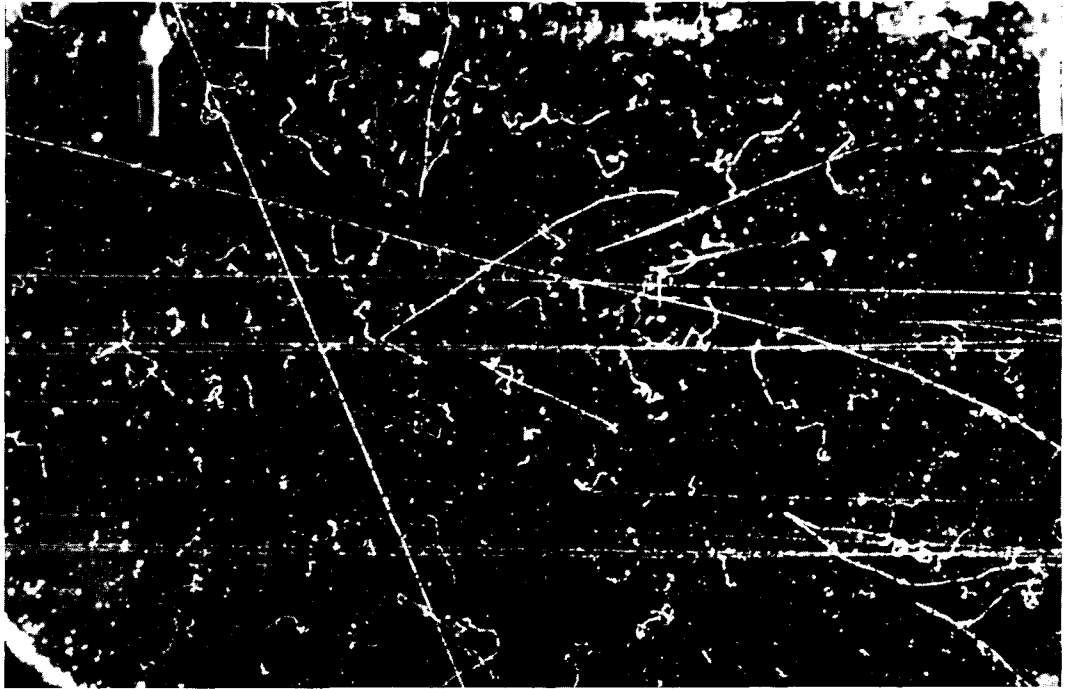


Fig. 2 Event obtained with the 50% propane — 50% methyl iodide mixture, using the 1 GeV π -beam. The four electron pairs probably result from the neutral decay mode of a K^0 meson.

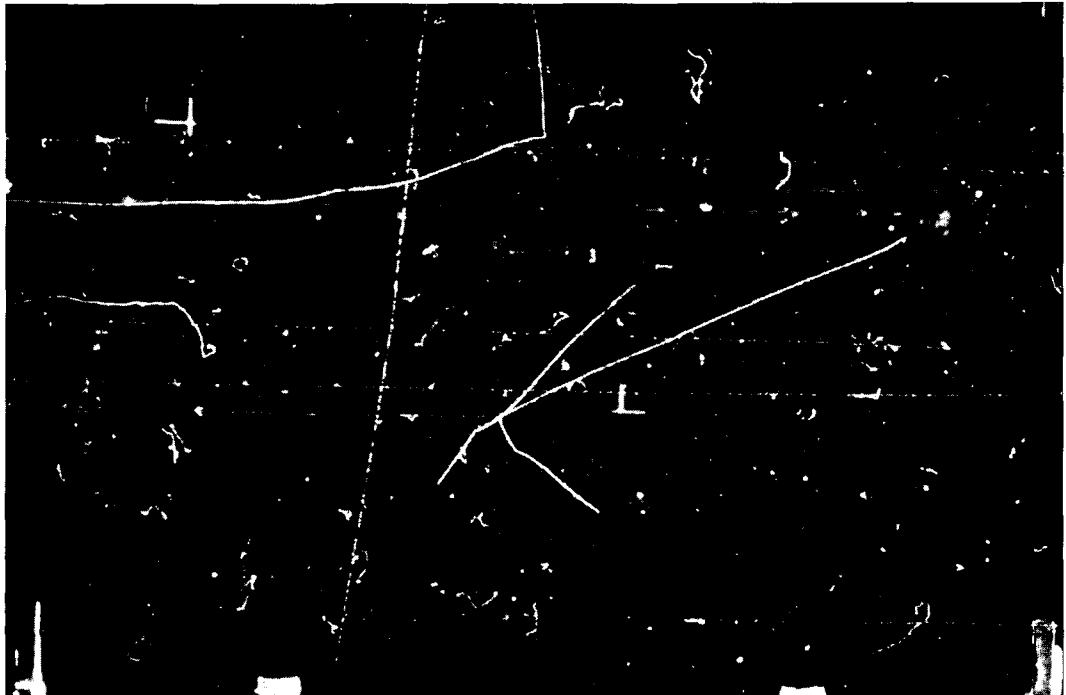


Fig. 3 Photograph obtained with the 50% propane — 50% Freon 13 mixture.

with the mixture of propane and methyl-iodide proved to be difficult.

In the early stages of the experiment partial decomposition of methyl-iodide after a few days of running caused a red colouring of the mixture with, as a result, non-uniform illumination. This colour disappeared when a copper plate was placed at the bottom of the chamber to absorb iodine.

This decomposition effect appeared quite sensitive to temperature and limited it to about 115°C in our chamber. It seems then that the chamber was slightly colder than required for optimum operation. In fact it was sometimes difficult to get more than 10 bubbles per centimeter.

After the completion of our experiment, we made test runs in the π^- beam using Freon 13 (CF_3Br) and a mixture of 50% propane, 50% Freon 13 by volume. Good operating conditions were found without difficulty in both cases.

The photographs shown in Figures 2 and 3 were obtained with methyl-iodide—propane mixture and with Freon 13—propane mixture, respectively.

THE ONE METER CHAMBER

An increase in the dimensions of a bubble chamber has many advantageous implications with respect to the experiments which can be performed with it. Some of them are obvious: increase of the number of interactions, improvement in detection efficiency for secondary particles, increase in the stopping power of the medium used, etc..

It should also be noticed that accuracy of momentum measurement in a magnetic field is improved. This point is especially important for heavy liquid chambers. The main error in the measurement for a particle travelling in a heavy liquid is due to multiple scattering. It can be shown that the relative error in momentum due to that effect is inversely proportional to $\beta H \sqrt{x X_0}$ where β is the velocity of the particle, H is the magnitude of the magnetic field, X_0 is the radiation length of the medium and x the length of the trajectory of the particle. Since the conversion length of γ rays is proportional to X_0 any improvement in photon detection is made at the expense of the accuracy in momentum measurements. This is the reason why no magnetic field was used with our 20 liter chamber.

On the other hand when the dimensions of the chamber are increased, x and X_0 (for given photon detection efficiency) increase correspondingly and a compromise between the two requirements above becomes possible. For instance, by using a mixture of 50% propane and 50% Freon 13 by volume (radiation length 20 cm), the detection efficiency will be around 85% for an energetic photon and a potential length of 50 cm, while the relative error in momentum due to multiple scattering is expected to be 10% for a relativistic particle travelling 50 cm in a 20 kG magnetic field.

The chamber

It is rectangular in shape and has dimensions $100 \times 50 \times 50 \text{ cm}^3$ (see Figure 4). In view of the ever-increasing number of liquids which could be used in bubble chambers, this chamber has been designed to be as versatile as possible. It can operate at temperatures up to 90°C and pressures up to 40 kg/cm². The body of the chamber is made of forged stainless steel to be able to operate with corrosive liquids.

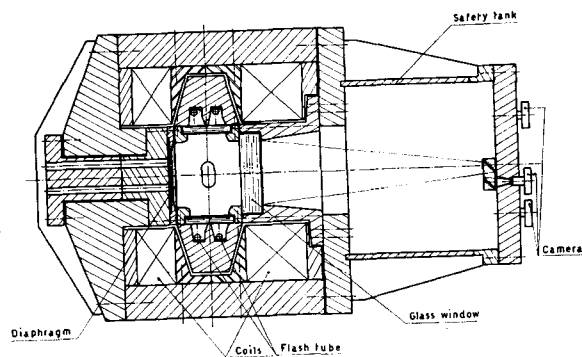


Fig. 4 Schematic drawing of the one meter chamber.

The magnet and the chamber proper are parts of the same unit, the yoke of the magnet being used to support the mechanical stresses occurring during the expansion and recompression cycle.

The main window is made of non-tempered optical glass 16 cm thick.

A welded steel safety tank capable of withstanding a pressure of 50 atm protects the operators in case of breakage of the main window. This tank will be

pressurized with helium and padded with thick rubber blocks in order to reduce possible shock effects. Similarly in case of failure of side windows and rubber diaphragm the liquid will remain enclosed in a pressure tight volume.

Photographic equipment

Four cameras will be used. The focal length is 180 mm with demagnification 1/10. Pictures will be taken through shielded prisms as a safety precaution.

Illumination will be performed by two sets of two flash tubes, one meter long, placed above and below the chamber. Light will be focused by parabolic cylindrical mirrors and will enter the chamber through 5 cm thick tempered glass windows.

Expansion mechanism

A rectangular Mylar and Perbunan diaphragm will be used. Expansions and recompressions will be controlled by "Barkesdale" valves triggering 12 "Grove" valves 5 cm in diameter. We expect to use 8 for expansion and 4 for recompression.

Expansion duration of less than 20 ms is expected.

Auxiliary expansion and recompression tanks will be connected to the chamber in such a way that the back part of the chamber can be easily taken apart.

The Magnet

The coils are designed to be operated at 600 V with a power of 4.5 MW or 2.25 MW. The two coils are of different sizes to compensate for the asymmetry of the pole pieces. The number of ampere-turns circulating in each coil can be adjusted if a 2.25 MW generator is used, to optimize field uniformity. Cooling of the coils is performed with water at a pressure of 25 kg/cm².

The total weight of the apparatus will be more than 80 tons including 12 tons of copper, 40 tons for the magnetic circuits and 30 tons for the chamber itself, the reservoirs, the framework and transport system.

Assembly will start in September 1959 and the chamber is expected to run at the beginning of 1960.

DISCUSSION

BAKKER: Could I ask Lagarrigue what the pressure will be in the safety tank? I understood that the pressure is higher in your chamber than in your safety tank: if something happened the whole safety apparatus would then just blow off—is that not right? So, I suppose the pressure in your safety tank has to be as high as in your chamber.

LAGARRIGUE: We have not yet decided the pressure in the safety tank, which has been calculated to operate in both of the two following conditions: *a)* We can put pressure intermediate between the higher pressure and the lower pressure in the chamber. In that case the strains on the window are minimum, but in case of breakage of the window we can have a shock effect on the door of the safety tank. This safety tank has been calculated to support such shock effect. *b)* But since the duration of time when the chamber has the lower pressure is incomparably shorter than the time when it has the higher pressure, we think that it will be better to have in the safety tank a pressure closer to the higher pressure. In that case it reduces considerably the probability of having a failure on the window in the direction of the door of the safety tank.

STRAUCH: It is our experience with a 50% methyl-iodide—50% propane mixture that if we use a faster expansion, of the order of 7 ms, instead of 20 ms, the chamber will operate satisfactorily at a lower temperature, of about 105°C, which should reduce the difficulty with the dissociation of the methyl-iodide somewhat.

EVANS: May I ask a rather more general question to all the people making propane and other heavy liquid chambers? Powell has pointed out the enormous task of analyzing the pictures. Now, there is a dodge which should simplify this enormously but it does pose tremendous engineering problems: that is to take two pictures at right angles in the chamber. If these can both be made plane projections, then the analysis is extremely simple. I think this was done in hydrogen first of all by Hildebrand, to my knowledge, and by Pless, I think, in propane. We repeated this for a 6 in. propane chamber, and it was very successful. Has anyone considered this possibility? I know the engineering problems are very severe.

ROSENFELD: I want to ask really a question about the question. Could you explain why 90° photography is much better than just stereo-photography?

EVANS: Yes. The point is this: that if you make one axis of photography parallel to the magnetic field lines, and if this is a plane projection, then you get the radius of the generating cylinder directly. That is a very simple measurement. From the other measurement at right angles to this, as it is also plane projection, you get the dip angle directly.

ROSENFELD: This simply then saves you using a computer?

EVANS: It makes the problem of the computer very much simpler. But it does add this enormous engineering problem.

I was asking if anybody has, in actual fact, studied this in detail. I have not.

POWELL: One of the things that prevented us from wanting to do that, was the problem of, in an event where there are several tracks coming out, being able to tell whether track number one in one picture was track number one in the other picture. Since scanning is a very large part of our work, we were rather prevented from using that method, or thinking about it very much, because of the difficulty, when the stereo

angle gets very wide, of identifying the individual particles correctly.

HILDEBRAND: We did a lot of scanning with 90° photography with the Chicago chamber, and we did not find that this was a serious problem since one co-ordinate was the same in each picture. It is a system we liked very much. It was very simple. The reason we have not pursued this is simply that iron is not transparent. When you put a magnet around the chamber it is hard to design a 90° optical system.

WINDOW SAFETY PROBLEMS IN BUBBLE CHAMBERS

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The danger associated with the possible failure of the window of a bubble chamber is a matter of serious concern. The usual design provides for a safety box to contain the propane as well as the fragments of flying glass, in case the window breaks. We have recently made some observations, using a small model chamber and safety box, of the dynamic pressure changes which take place when the window breaks. A single line sketch of the inside dimensions of the testing arrangement is as shown in Figure 1. Windows (W) of $\frac{3}{8}$ in. thick plate glass broke at approximately 475 lbs/in² and of $\frac{1}{8}$ in. at approximately 100 lbs/in².

Many windows have been broken under various conditions and the results of certain cases are shown in Figures 2 to 5. The pressure indicated by the transducer is plotted as a function of time. Figure 2 for the case of a simple gas, helium, is in the nature of a check of the equipment. The pertinent data

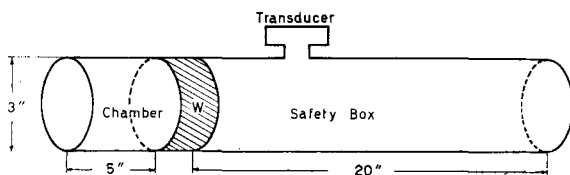


Fig. 1 Sketch of the testing arrangement.

are given there. One sees the initial rapid rise of the pressure, in about one-half millisecond, and a slower later pressure rise perhaps corresponding to the gas coming into temperature equilibrium with the walls.

Figure 3 is for propane. It should be noted that the chamber is hot and the end of the safety box is at room temperature. When the window breaks there is a short initial delay followed by a rapid rise, in about 5 millisecond, to a pressure of about 140 lbs/in² which is followed by a slower rise to 220 lbs/in². Thus it is clear that the propane boils fast enough to do a very efficient job of propelling

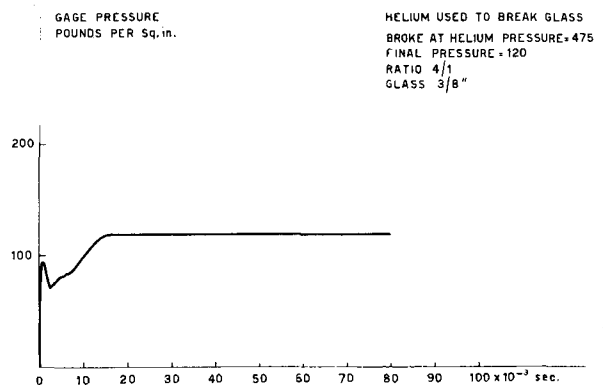


Fig. 2 Pressure versus time for the chamber filled with helium.