HIGH-ENERGY PHYSICS WITH A LARGE HEAVY-LIQUID BUBBLE CHAMBER

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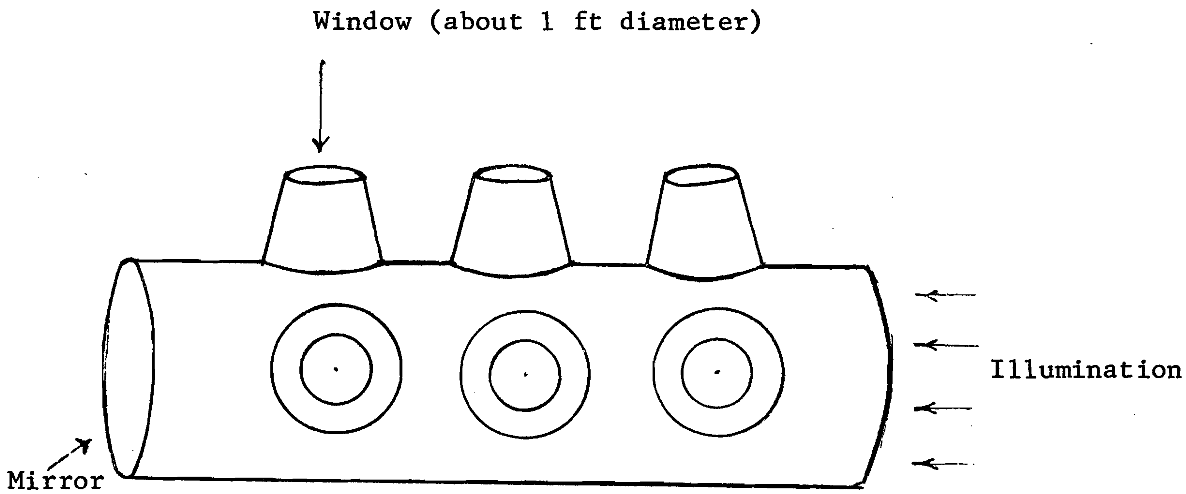
The purpose of this report is to try to take a look at the next generation of bubble chambers. The details of such chambers are strongly influenced by what sort of physics is to be done with these instruments. In the past, bubble-chamber analysis has relied largely on momentum measurements and then kinematic fitting done on frequently-found events. As one raises the energy of the incident particles, the fraction of analyzable events decreases monotonically. If further progress is to be made, we probably will have to increase our analysis power.

Let us consider building a chamber in which essentially all of the particles coming from the initial interaction will themselves interact in the chamber. I will consider only heavy liquids in this report, but some of the conclusions may carry over to H_2 or He chambers. The mean free path for interaction in propane or freon is about 1 meter so that such a chamber should have a dimension of several meters. The general size that we are considering is a cylinder of 2-meters diameter and 7 meters in length. Thus, any particle coming from a reaction would have to traverse several mean free paths of material.

As noted above, the chamber would basically be a cylinder. I would propose a multiwindow chamber. This means that, in principle, one could extend the chamber by adding additional sections. The following sketch illustrates the sort of chamber envisaged.



The reason for considering a multiwindow device is mainly the extremely long delivery times of the large glass windows. The long delivery time and great expense produces great psychological and physical barriers in fabrication and manipulation of the chamber. The chamber would be viewed through relatively small ports. There is optical distortion as a result of viewing through the optically-dense medium. It is possible that this can partially, at least, be corrected for by something like a Schmidt plate. Right-angle stereo is proposed to increase accuracy in reconstruction.

For a magnetic field, I propose a transverse field between 5 and 10 kgauss. This would give an accuracy in momentum measurement of between 30% and 15% for the average strongly-interacting track.

L.M. Lederman (Columbia): That's in propane. Therefore in freon it would be almost useless.

W.D. Walker: You might be able to tell the charge in freon.

To produce a field of 5 kgauss would require the order of 5 megawatts of power. Pulsing may be feasible.

We would use right-angle illumination produced by lights located at a series of ports on the downstream side of the chamber.

The obvious place for such a chamber would seem to be in a ν beam. The proposed chamber would have an active mass of about 15 tons if filled with a mixture of CF_3Br and ethane. Based on results at CERN, one could expect a yield of the order of 50-100 neutrino events per day. Thus, if there were an effective cross section for some particular reaction, of the order of 10^{-40} cm^2/nucleon, one might expect 1 event per day.

Such a chamber would be extremely useful in differentiating μ's and e's from other particles. The probability of a strongly interacting particle traversing 4 meters of chamber is only of the order of 2%.

One might look for the process

$$\nu + Z \rightarrow W + \mu + Z, \quad W \rightarrow \mu + \nu$$

This would show a signature of 2 μ's coming out of the chamber. The chance of a pair of π's appearing like this is $\sim 5 \times 10^{-4}$.

The chamber would be extremely useful in looking at processes such as $\nu + p \rightarrow \Lambda^0 + \mu$ where the high spatial resolution would be of great value. The differentiation of μ's and e's from other particles would be relatively simple in such a chamber.

If one wanted to do strong-interaction physics at energies of 5-10 Bev, then it would be highly desirable to have a higher magnetic field.

The cost of such an instrument is difficult to estimate. Some items are to be used exclusively in conjunction with the chamber. These items are to be charged completely to the chamber. Other things like the power supply may be generally useful and shared. There will be a difference in cost of magnet and power supply of a factor of between 2 and 3 depending on whether one wants a 5 or 10 kgauss field.

The chamber building, plumbing, reservoir tanks, liquid, optics, camera system, compressors, and electronic controls would amount to the order of $750,000 exclusive of personnel. The cost could be less or greater than this depending on the magnetic-field requirements. The compressor and the freon would each represent $100,000 of the total amount.

Discussion

W.B. Fowler (BNL): Have you considered how long it might take to build such a device?

W.D. Walker: I think that it's relatively straightforward to build such a thing. I think that the expansion mechanism offers some difficulty. By being clever you can decrease the amount of compressor that you use. For example, you might even think of building an expansion system which works something like a diesel engine, in which you actually use some sort of fuel to recompress the chamber. But by not being clever --

by being straightforward -- you can go ahead and buy standard large compressors. I don't see any great difficulty in the fabrication of the tank. The tank looks simple, but large. You get into binds when things get this large, because there aren't many places that can machine such a piece of metal. The engineering looks quite straightforward. Consequently, I don't believe it would take so long -- probably several years.

L.M. Lederman: Have you considered the usefulness of this compared to, say, a thinner-plate spark chamber?

W.D. Walker: I really haven't tried to do it in detail. I've always had the feeling that it's a qualitative question -- how much additional information you get by being able to see the track from production to exit. I don't know what it is possible to do with a spark chamber, for example.

L.M. Lederman: Basically, it changes spatial resolution from something like 1/8" down to about 10 μm.

W.D. Walker: Yes, for example. You would say that one of the backgrounds when you are looking at this reaction

$$\nu + (Ze) \rightarrow \mu + W + (Ze), \qquad W \rightarrow \mu + \nu$$

would be the case where you produce a pair of pions and the pions decay in flight. The probability of the pions going out without decaying in flight or interacting is comparable. If you ask if you can identify a pion decaying in flight inside the liquid, the answer is probably no.

R.D. Sard (Illinois): How does this compare with using the hydrogen chamber with many plates in it for looking at the W reaction?

W.D. Walker: I think it is just a matter of the 15 tons of liquid. If you put propane in the chamber, then you'd have something like 3 tons of hydrogen in the chamber so you might compare the three tons in this chamber with a hydrogen chamber of a rather comparable size. It's just a matter of tonnage as far as the chamber is concerned. I think it would be quite an engineering undertaking to build a hydrogen chamber of this size. I believe this is cheap compared to hydrogen.