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RECONSIDERATION OF A SPHERICAL 25-FOOT BUBBLE CHAMBER IN THE LIGHT OF TRACK-SENSITIVE TARGETS

R. Palmer and R. Huson
Brookhaven National Laboratory,

M. L. Stevenson
Lawrence Radiation Laboratory,

C. Baltay
Columbia University,

B. Roe
University of Michigan

and

H. Wachsmuth
University of Wisconsin

ABSTRACT

Many advantages of a spherical design are presented. The size of track-sensitive target that can be used is increased from 10 k liters to 35k liters. Engineering, optics, trapping, and experimental convenience are all improved. The increased cost is small and might be completely offset if it proves feasible to operate with deuterium inside the target and neon-hydrogen outside.

Use of Spherical Shape

Before listing the advantages, we must first consider the cost. It is noted (see Fig. 1) that no change is proposed in the magnet, the vacuum tank, the supports, etc. The chamber itself, being simple, is not expected to cost more despite its somewhat larger weight. The expansion system cost might be proportional to the volume in which case the extra cost would be about $300, 000.

This seems a small price to pay for an increase in volume by a factor of 1.6. Indeed, the spherical shape was very seriously considered by R. P. Shutt and W. B. Fowler. It is our understanding, however, that it was rejected for the following reasons:

1. The 1968 NAL Summer Study recommended 2:1 for the ideal aspect ratio.
2. The increase in deuterium cost ($3 M).
3. The increase in depth through which to photograph.

These objections were raised, however, without consideration of the chamber's use with a sensitive target.

Aspect Ratio

M. L. Stevenson[1] has calculated γ-conversion efficiencies for sensitive targets both in the presently proposed 25-foot and in a spherical version. Assuming a 70-cm conversion length in the Ne-H_2 mixture and requiring a 70% conversion efficiency for two γ-rays emitted in the forward 2π, he obtains a sensitive target volume of 11,000 liters in the present 25-foot design. If a spherical design were adopted, the volume of the target for the same efficiency would be over 50,000 liters. No account was taken in this estimation of the inability of the lenses to focus down to very near distances, but the effect would be similar in the two cases, and the conclusion will remain that very much larger sensitive targets could be used in a spherical chamber.

We can reverse the logic and ask what would be the correct aspect ratio for a chamber intended for use with a sensitive target. For the shape of the target, we can take the 1968 Summer Study calculation that its length should be 2 times its diameter. If we surround the target with 50% Ne-H_2 and require 3 γ conversion lengths, then the thickness of Ne-H_2 is 7 feet. If the total length is 21 feet we have for the dimensions of the target 14 feet $\times$ 7 feet diameter and the dimensions of the chamber 21 feet $\times$ 21 feet diameter, i.e., aspect ratio 1:1.

The argument can be made that the Ne is not required at the sides since high energy π^0's will be emitted forward. Even if this were true, and it will not always be, there are other reasons for the Ne at the sides. For instance the Ne will give polarization information on the charged particles that enter it and will provide μ-π separation in neutrino events. Since the field bends such charged particles, they do not remain in the forward direction even if so produced. Some compromise has to be reached, but it is clear that the use of a target does dictate a smaller aspect ratio and a sphere has obvious simplicity.

Deuterium Cost

The second objection to a spherical chamber was the increase in cost of dueterium. This argument, too, we believe is not true when sensitive targets are considered. We mentioned in passing the volume of 50,000 liters for a sensitive target in a spherical chamber. Even if this is unreal, a volume of 35,000 liters in such a chamber looks reasonable (see Fig. 1). Such a volume is only a factor of two less than the total visible volume in the unmodified chamber. The question can now be asked of the neutrino experimenters: "Which would you prefer, 70,000 liters pure deuterium, or 35,000 liters deuterium in a target surrounded by Ne or Ne-H_2?" The answer appears to be the latter. We thus conclude that only 35,000 liters of deuterium need be bought thus saving ~2.7 million dollars. It should be noted that the answer to the same question in the context of the present chamber would be less likely to favor a deuterium volume of only 10,000 liters. The saving in deuterium cost would more than cover the extra cost of the chamber and probably the neon cost as well.

Increased Depth

The final objection to the spherical design was the increase in depth through which to photograph. This objection may prove to be unfounded when results from the 7-foot and 12-foot chambers are available. However, if it was justified, it can be overcome by inserting two "high-precision cameras"[2] on stalks into the sphere. A stalk of 3 feet in length would bring such cameras into the same position as in the unmodified design. A larger stalk would bring the precision lens down to the wall of the sensitive target and would avoid the distortion introduced by photography through the target wall. Other lenses would still be provided to see the whole chamber and observe the γ's produced outside the target region.

It has also been objected that the requirement of fitting the greater width onto 70 mm film would necessitate a lower magnification. This is a price always paid for a larger chamber, but it does not basically reduce the accuracy since the images will not be film-resolution limited. If required, the old magnification could be maintained and still a sizable gain in visible volume achieved. Alternatively fiducial volume lenses could be used to augment the main cameras and provide higher magnification images of a more limited volume.

Advantages

In conclusion, we will list these and other advantages gained by making the chamber spherical:

1. Volume of sensitive target increased by about 4 times.
2. Total volume for $Ne\text{-}H_2$ neutrino experiment increased by 1.6 times.
3. Trapping momentum increased by 1.4 times.
4. Lens field angle reduced from 120° to 100° and length of lens feed through reduced.
5. Beams can be brought into the chamber from any direction, thus removing the need to rotate the chamber.

REFERENCES

[1] M. L. Stevenson, High Energy Neutrino Physics and the Constraints Placed on the Detectors, National Accelerator Laboratory 1969 Summer Study Report, SS-74, Vol. IV.

[2] R. B. Palmer, A Proposal to Increase the Precision of the 25-foot Bubble Chamber," National Accelerator Laboratory 1969 Summer Study Report SS-84, Vol. II.

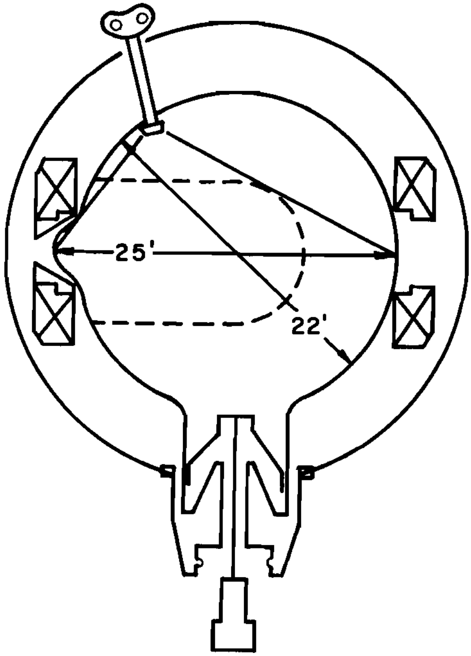

Fig. 1. Spherical design for the 25-ft bubble chamber showing position of track-sensitive target.