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S. De Schryver, L. Fiore, E. Lodi-Rizzini, G. C. Mantovani, I. Modena, A. Piazza, F. Scaramuzzi and G. Susinno :
TECHNICAL REPORT ON THE APPARATUS FOR AN EXPERIMENT OF TWO π^0 PHOTOPRODUCTION IN HYDROGEN WITH A HEAVY LIQUID BUBBLE CHAMBER.
Part I : THE HYDROGEN TARGET.

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ABSTRACT. -

The construction of a hydrogen target to be inserted in a freon bubble chamber is described. The problems posed by the use of a photon beam are discussed. The best solution seems to be a thin-walled gaseous target at high pressure placed in a small region near the chamber center. The results of a Monte Carlo efficiency calculation are also reported. The apparatus will be used at the Frascati Electronsynchrotron to investigate the double π^0 photoproduction on protons.

I. - INTRODUCTION. -

The problem of inserting a hydrogen target inside a heavy liquid bubble chamber can be solved in different ways according to the beam used and to the characteristics of the reaction to be analysed(1, 2, 3).

We inted to investigate the double neutral pion photoproduction on protons by using a bremsstrahlung photon beam and a freon bubble chamber. In designing the internal hydrogen target, the following requirements have to be taken into account:

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i) The photon beam has to cross the whole chamber inside a vacuum tube to avoid producing an electromagnetic shower in the freon. Since this requirement causes a loss of forward produced events, the tube has to be as small as possible.

ii) The small ratio of the cross-section for the events under study with respect to the electromagnetic cross-section in hydrogen (1/200 or less) suggests a target as long as possible in the beam direction. By so doing, in fact, the electron-positron pairs, produced in the hydrogen and swept by the magnetic field, are distributed over the whole visible zone of the chamber producing a low density of background tracks.

iii) The angular distribution of the π^o produced in the investigated process

$$\gamma + p \rightarrow p + \pi^o + \pi^o \quad (\pi^o \rightarrow 2\gamma,\ \pi^o \rightarrow 2\gamma) \qquad (1)$$

is slightly peaked in the forward direction, so that the decay γ-rays are distributed in a quasi-uniform way around the interaction point. From this it is easy to see that the best arrangement which gives a detection efficiency not strongly angle and position dependent consists in placing the hydrogen target in the central region of the chamber, so trying to satisfy both the requirements ii) and iii) by a suitable choice of the target length.

We have chosen a H_2 gaseous target extending for 15 cm along the beam direction, placed in the central zone of the chamber and contained in a tube with diameter and thickness as small as possible.

The lower density of the gaseous hydrogen with respect to that of the liquid one (a factor about 5, if a pressure of 150 atm is used) is not a disadvantage, because in any case the incident photon flux has to be reduced for the reasons explained in point ii).

In the following the technical details of the target and some results of the Monte Carlo calculation from which we derived the proposed arrangement, are reported.

II. - TECHNICAL DETAILS. -

In Fig. 1 a schematic drawing of the target inserted in the bubble chamber is shown. The bubble chamber (ϕ 50 x 38 cm^2) is operated with a mixture of CF_3Br and CF_3Cl(4) at an equilibrium pressure of 19.5 atm and at a recompression pressure of 35 atm, at room temperature. The mixture density is 1.5 g/cm^3 and its radiation length is 11 cm. A complete description of the chamber and of its operation will be the object of the second part of the report.

The hydrogen target was constructed as shown in detail in Fig. 2. The hydrogen gas, at a pressure of 150 atm, is contained

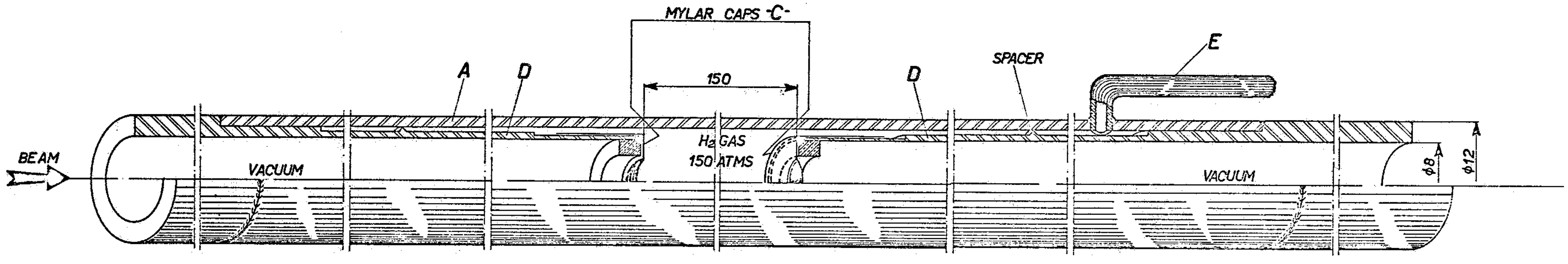

FIG. 1 - Schematic drawing of the target inserted in the bubble chamber.

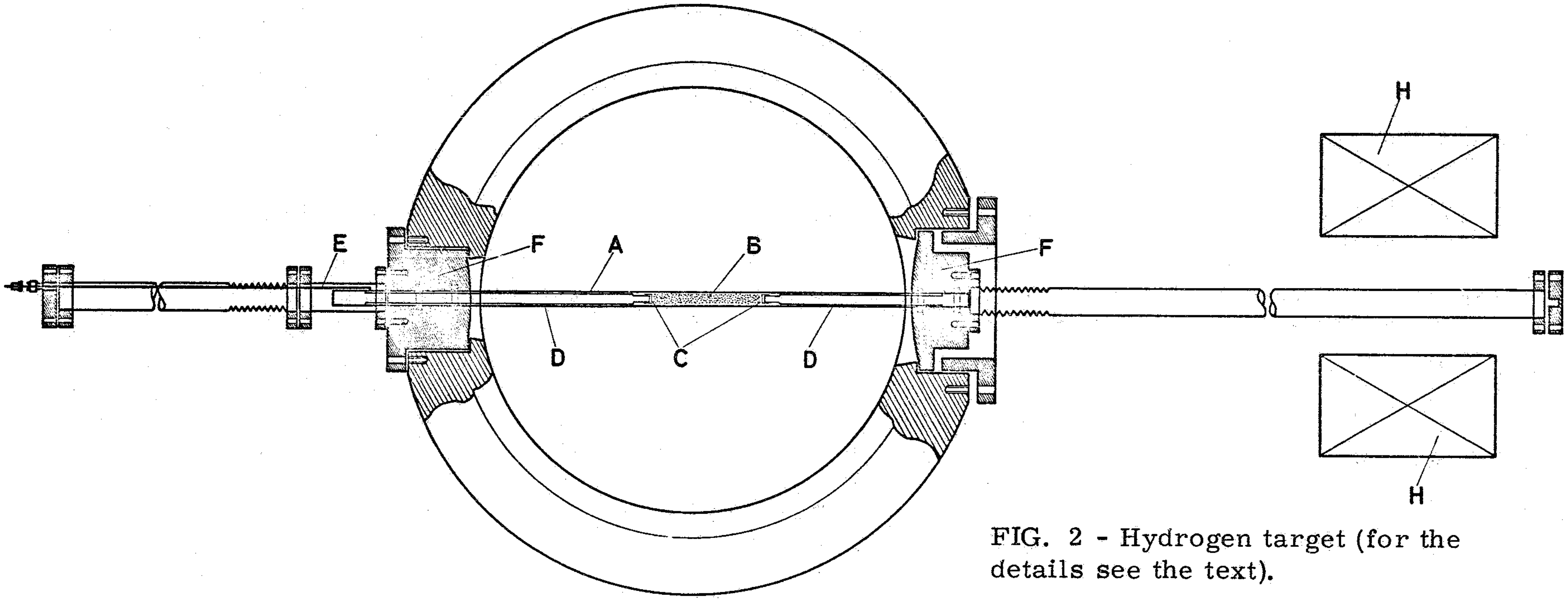

FIG. 2 - Hydrogen target (for the details see the text).

in the stainless steel tube A, with a wall 1 mm thick, chosen to withstand the bubble chamber pressure. Two stainless steel coaxial tubes D are hard soldered to the tube A, ending with mylar caps C, in order to confine the gas in a shorter region (150 mm). Vacuum is maintaned on the outer sides of the mylar caps.

The mylar caps were previously shaped out of a 0.015" thick mylar film in a cylindrical form, so as to fit onto the extremities of the D tubes. The shaping procedure consists in heating the film while pressing it in a metal mold: in this way the thickness of the mylar windows is reduced to about 0.25 mm. Then the caps were cemented to the D tubes with UHU glue. Finally the system as a whole was tested under pressure. Duration tests and rupture tests were also made. In the former, a pressure of 150 atm was applied for more than one month, with no noticeable change in pressure. In the latter, rupture pressures between 250 and 300 atm were measured.

The connection of the target to the gas source is made through the copper capillary E (ϕ_{int} = 1 mm), hard soldered to tube A outside the chamber. This arrangement allows the cell length and its position with respect to the bubble chamber center to be easily changed.

The insensitive volume is very small (less than 3 %) and the thickness of material crossed by the reaction products before entering the sensitive liquid is not very important as regards the probability for γ-ray conversion and proton scattering (about 15 %). Furthermore, it must be noted that because of the small thickness of the mylar windows ($\sim 6 \times 10^{-4}$ r. l. corresponding to a thickness of $\sim$ 2 cm of gaseous H_2 at 150 atm) the target may be really limited to the central zone of the chamber.

III. - DETECTION EFFICIENCY. -

As said before, the arrangement of our hydrogen target was chosen on the basis of the results of a Monte Carlo event generator program, worked out on purpose for our particular experimental conditions, starting from an already existing program.

Our program had several purposes, some of which do not concern the present note :

i) To evaluate the detection efficiencies of our experimental apparatus, that is, the probability of detecting the proton only, or of the proton plus one converting γ-ray, or two converting γ-rays and so on up to one proton plus four gammas.

ii) To find the best arrangement for the hydrogen target.

iii) To prepare an output tape containing the complete simulation of event measurements of reaction (1) in the format required by the kinematical reconstruction program in order to verify its efficacy in our particular case and to study the necessary modifications.

iv) To obtain the best measurement method to minimize the multiple scattering error and to optimize the fitting procedure.

The basic program was NVERTX, compiled at the Harvard University, which can generate any type of event with up to 20 vertices in the empty space (i. e. without reference to any particular experimental situation), according to a purely statistical distribution (phase-space) or also taking into account any number of possible resonances between the various reaction products. Our experimental situation was introduced in the program by adding a suitable routine to transform each event generated in the empty space into a measurement of the event itself, as might be obtained with conventional digitized apparatus on bubble chamber pictures.

This routine transfers each event generated by NVERTX in our freon bubble chamber, i. e. assigns to each track the vertex coordinates, the length L according to the calculated energy (if stopping), the curvature $1/\rho$ according to the calculated momentum and to the magnetic field value, the dip λ and the azimuth φ angles, the errors associated with each quantity (due to the multiple scattering for the protons, radiation losses for the electrons, measurement inaccuracy and so on) and finally the correlations among them. In Fig. 3 the flow chart of the routine is shown. By so doing, each event was completely simulated and we were able to make the necessary previsions according to the list above. As to the target arrangement the calculations of the overall detection efficiency were carried out for several lengths and positions.

The results of the calculations are shown in Table I. The various percentages correspond to the following cases:

i) Detected proton plus no γ -ray;

ii) Proton plus one γ -ray, and so on.

Since the kinematics of the reaction (1) are over-determined also when only three γ -rays are detected, the efficiency of the columns six and seven in Table I can be summed .

In Fig. 4 the overall detection efficiency versus the position of the target center is shown. The point $x = 0$ corresponds to the bubble chamber central point.

From this graph the choice $x = -5$ cm for the target center and $l = 15$ cm for its length, is the best for our purposes.

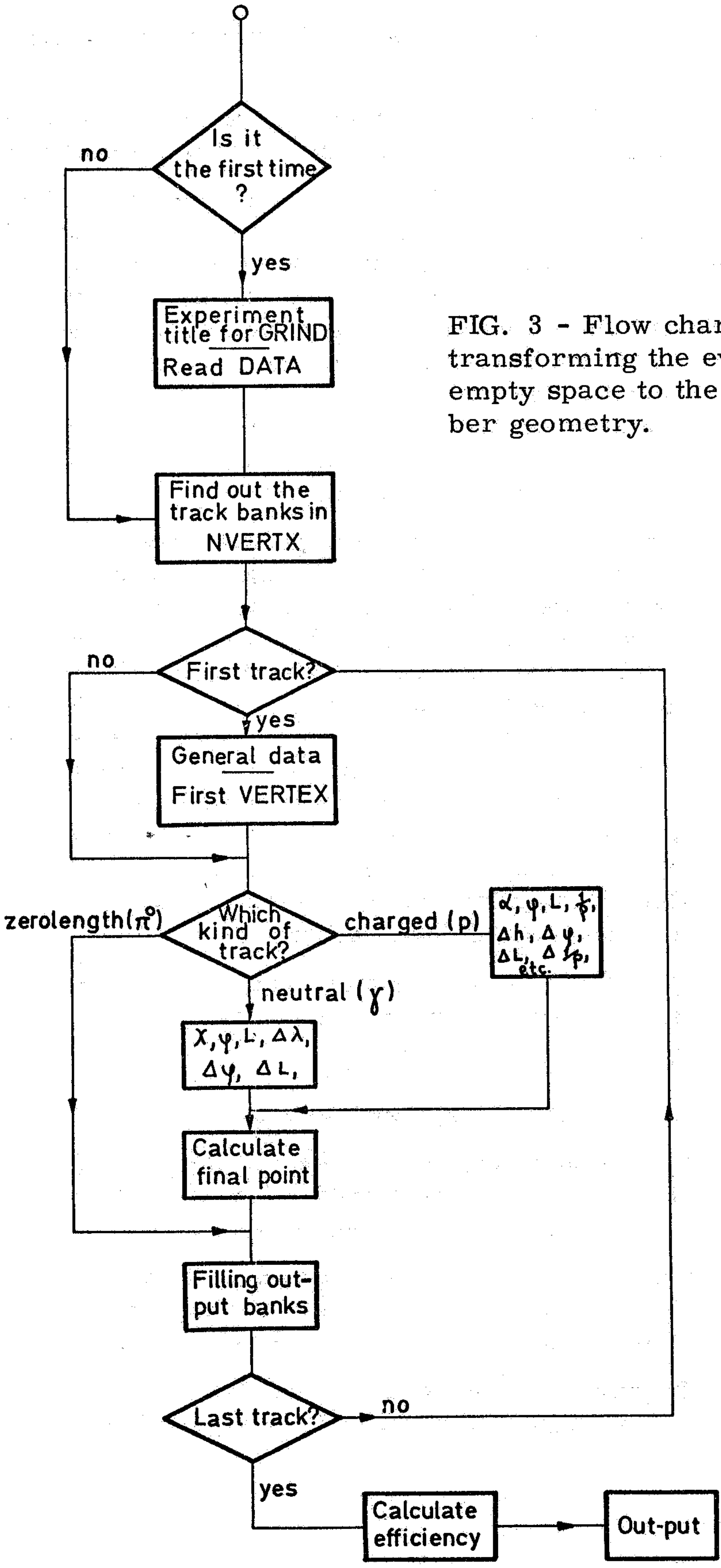

FIG. 3 - Flow chart of the routine transforming the events from the empty space to the bubble chamber geometry.

TABLE I

Calculated detection efficiencies

x is the target center position assuming x=0 for the bubble chamber central point. ε_k is the detection efficiency for the proton plus k γ-rays. For the case of two revealed γ-rays the efficiency is given separately depending on whether one (ε_2^1) or two (ε_2) π^o are involved. ε_p is the efficiency of seeing the proton irrespective of the gammas.

x	ε_0	ε_1	ε_2^1	ε_2	ε_3	ε_4	ε_{3+4}	ε_p
-22. 5	0. 098	0. 336	0. 059	0. 247	0. 181	0. 031	0. 212	0. 952
-17. 5	0. 037	0. 213	0. 052	0. 266	0. 283	0. 074	0. 357	0. 925
-12. 5	0. 028	0. 198	0. 056	0. 262	0. 293	0. 096	0. 389	0. 933
- 7. 5	0. 021	0. 168	0. 062	0. 254	0. 334	0. 110	0. 444	0. 949
- 2. 5	0. 033	0. 162	0. 060	0. 223	0. 349	0. 105	0. 454	0. 932
2. 5	0. 027	0. 214	0. 048	0. 229	0. 315	0. 090	0. 405	0. 923
7. 5	0. 039	0. 224	0. 056	0. 247	0. 275	0. 073	0. 348	0. 914
12. 5	0. 061	0. 267	0. 058	0. 270	0. 215	0. 038	0. 253	0. 909
17. 5	0. 134	0. 353	0. 044	0. 190	0. 105	0. 006	0. 111	0. 832
22. 5	0. 152	0. 155	0. 006	0. 037	0. 010	0. 000	0. 010	0. 360

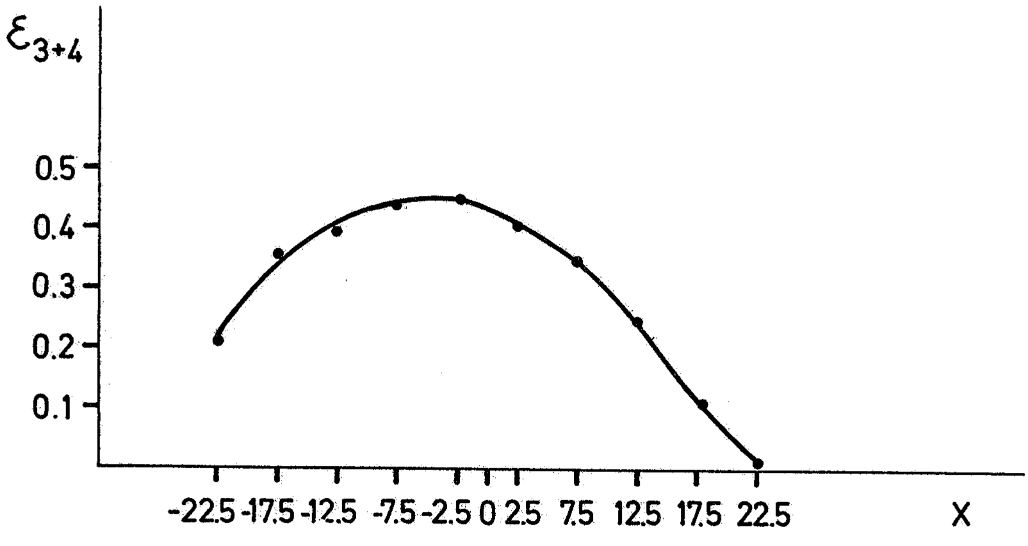

FIG. 4 - Overall detection efficiency (ε_{3+4} of Table I) versus the position of the target center. The point x=0 corresponds to the bubble chamber central point.

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