A LIQUID HYDROGEN/DEUTERIUM TARGET WITH VERY THIN WINDOWS*

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(Received August 31, 1993)

The development of a thin target for liquid hydrogen isotopes with extremely thin windows is described. Its importance for external cooled beams is discussed.

PACS numbers: 25.26. Pj

1. Introduction

The new Cooler Synchrotron COSY at Jülich will provide an excellent phase space cooled beam, which allows the use of very small target volumes. The combination of phase space cooled beam and small targets is of considerable interest in nuclear physics experiments in order to get a well defined interaction vertex, which is quite important for the quality of the kinematical reconstruction. Furthermore, the systematic errors, due to Coulomb scattering and secondary interactions in the target are reduced. Moreover, there is a good chance to detect and trigger particles with a low $c\tau$-value of several cm. For acceptable counting rates, a small target volume is not possible with a gas cell. One has to liquefy the gas to increase the density by a factor of 4000 (for H_2, D_2 at 200 mbar).

The construction of liquid targets with a length between 1 and 10 mm, we are developing for external experiments at COSY, is affected by several requirements:

- The target liquid has to be without any bubbles because of the large density difference between liquid and gas. For a target with a length of 5 mm a bubble can reduce the effective target thickness by about 50 % and leads to unreproducible results.

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* Presented at the Meson–Nucleus Interactions Conference, Cracow, Poland, May 14–19, 1993

- There is need for extremely thin target windows, which are thin in the sense of reaction rates in comparison with the target material in order to reduce background events caused by the window material and to reduce the energy loss and straggling of the ejectiles.
  "Conventional" liquid hydrogen or deuterium targets are large cylinders with a length of several cm and liquid under atmospherical pressure inside. Hence, the cylinders are sealed up by thick Mylar foils ($\geq 100\,\mu$m), which leads to a ratio of reaction rates from window material to target material of 0.1. For our targets, we use 1.5 μm Mylar foils in order to reduce the amount of background in the reaction rate about 1 % for a target length of 5 mm. Therefore, the pressure difference between the inside and the outside of the target cell has to be stabilized to a small constant value under all target conditions.
- The target thickness should be well defined. For this, we need a target liquid with a homogeneous density and target windows without curvature and perpendicular to the beam.
- Furthermore the target form should have axial symmetry because of the axial detector symmetry following the target.

2. Thermodynamics

The lowest possible window thickness is achieved for the lowest possible pressure difference between the inside and the outside of the target cell. The first external experiments at COSY require liquid hydrogen and deuterium as the target medium. Fig. 1 shows the phase diagrams of these two matters:

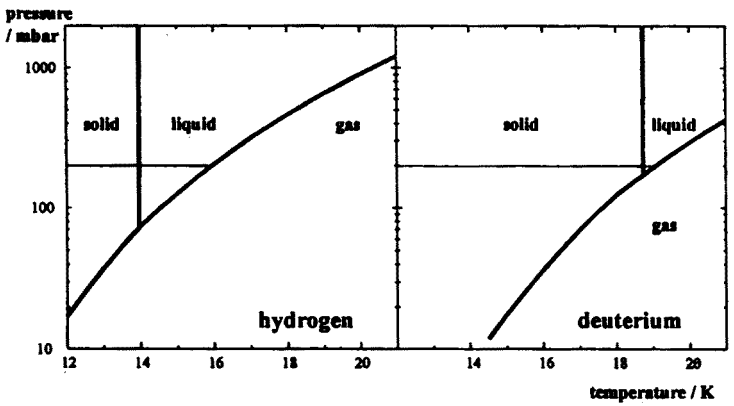

Fig. 1. Phase diagrams of H_2 and D_2 (from Landolt-Börnstein).

A gas can be liquefied, if the pressure is higher than the triple point pressure of the gas. For our target a fixed working pressure of 200 mbar is chosen,

which allows the use of hydrogen, deuterium, oxygen, nitrogen and helium (with a more powerful cooling machine) by a simple gas change without variations of the target apparatus. The triple point of hydrogen is at 72 mbar and 13.95 K, which is far bellow the 200 mbar mark. Thus, there is a temperature range of about 2 K, where hydrogen is liquid at 200 mbar. Our cooling machine attains 14 K, so there is no risk of freezing the hydrogen. The triple point of deuterium is at 171 mbar and 18.72 K, which is very close to the 200 mbar mark. The temperature range, where liquid deuterium exists at 200 mbar is just 0.4 K and therefore a stabilized temperature control is necessary.

3. Stabilization system

A stable low pressure difference between the inside and the outside of the target cell is obtained by using a mechanical stabilization system, first described in Ref. [2].

A schematic setup is shown in Fig. 2. The gas reservoir and the target cell are installed in the same tank, which can be evacuated to 10^{-6} mbar. For the reservoir we use a very flexible cylindrical metal bellow with a lead mass on top. The pressure in this bellow, resulting from the lead mass alone is 200 mbar. The reservoir is connected with the target cell, which can be cooled down.

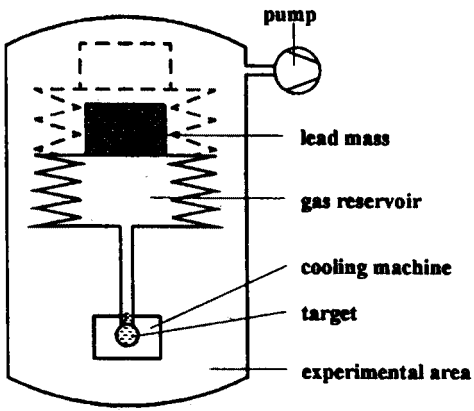

Fig. 2. Schematic setup of the stabilization system.

The pressure in the gas reservoir and therefore in the target cell is the sum of the pressure in the experimental area and the pressure resulting only from the lead mass. Hence, the pressure difference between the inside and the outside of the target cell is constant at 200 mbar, resulting from the lead

mass. The target operation starts with normal pressure in the experimental area. After evacuation the bellow expands by a factor of six. If the target cell is cooled down, more and more of the gas is liquefied. The bellow shrinks, but the pressure difference is constant at 200 mbar, which enables the use of very thin target windows.

4. The target cell

Fig. 3 shows a cut through our last target generation in side-view and front-view. In the beam region the target apparatus consists of a copper head, which can be cooled down to about 14 K by a refrigerator cold head. Inside of this copper head, the gas is liquefied and the target tube is filled with liquid. The openings for the COSY beam are pasted up by 1.5 μm Mylar foils with epoxy resin glue.

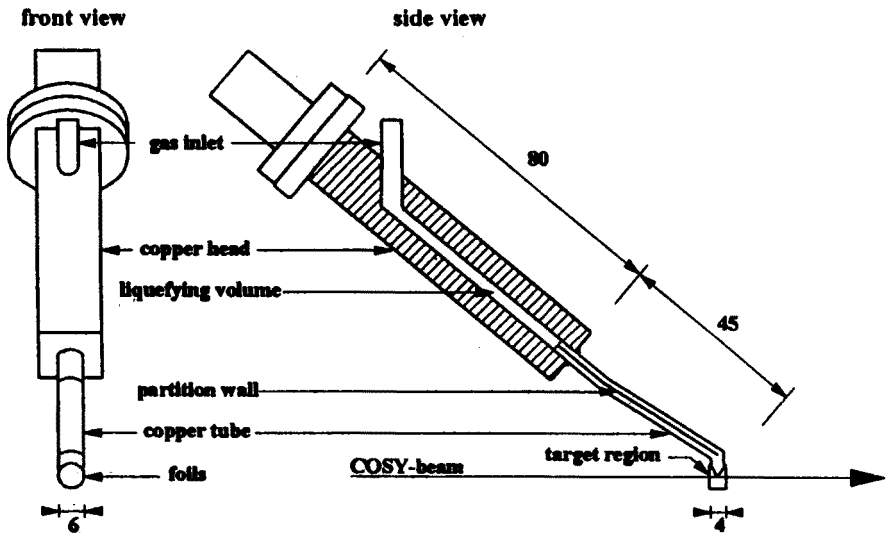

Fig. 3. Target in front-view and side-view (unit of measurement in mm).

In order to get a target region free of bubbles the tube is divided by a thin aluminium wall. This partition wall enables free convection: the cold heavy liquid runs down on the lower half, because the whole arrangement is tilted relative to the beam direction. The liquid from the target region, heated up permanently by infrared radiation and the incident proton beam, streams up on the upper half and is cooled down in the liquefying volume again. The convection has to be so strong that in the lowest part of the target bubbles are suppressed. In the worst-case the incident proton beam

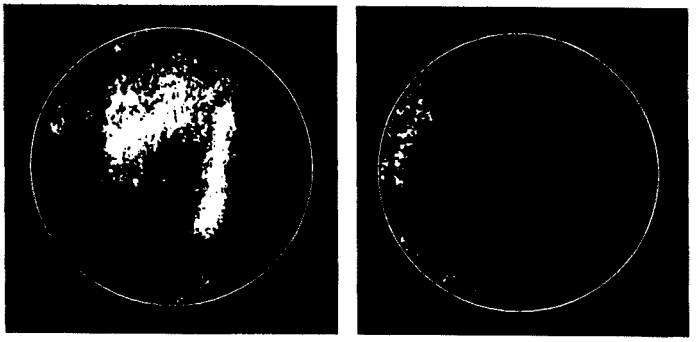

Fig. 4. Schlieren pictures from the target cell; *left*: cell at the beginning of the liquefication; *right*: cell at 14 K.

(10^{10} protons per seconds with 500 MeV/c) deposits 0.96 mW in a liquid hydrogen target with an inner pressure of 200 mbar and a length of 6 mm. Without cooling this heating power would increase the temperature of the liquid by about 1 K in 3 s. This is uncritical because the convection renews the target liquid much faster.

In order to reduce the thickness of the tube material it is completely made galvanically: first a core with the desired target form is made by using a special bismuth alloy (melting point 130^0 C). This core is galvanically copper plated with a layer thickness of several μm (up to now a tube thickness of about 70 μm is used). The alloy is detached under heating and cleaning in some stripper solvent. The result is a thin copper tube with a target length of 4 mm and an inner diameter of 6 mm at a distance of 45 mm to the copper head, which represents the limit of our liquefying volume. We get 1.5 cm^3 LH_2 and 1.3 cm^3 LD_2 and therefore the safety risk is quite small.

The target cells are checked by the Schlieren method which shows very low variations of the refractive index of the target liquid, caused by variations of the density. Fig. 4 shows two Schlieren pictures from the target cell filled with LH_2, which are treated by some scanner software. The white ring represents the edge of the target cell and the white regions in the cell indicate density variations in the liquid.

At the beginning of the liquefication the upper region of the cell is full of Schlieren because from above the cold liquid comes from the copper head and mixes itself with the relatively warm liquid in the target region. At 14 K the cell is very calm, without any bubbles and with density variations of a few ppm. As a next step the Mylar foil thickness has to be reduced down to 0.9 μm which is the thinnest available foil thickness in order to construct targets with a length of 1 mm by an acceptable background rate.

REFERENCES

[1] Landolt-Börnstein, *Zahlenwerte und Funktionen*, Vol.2: *Eigenschaften der Materie in ihren Aggregatzuständen*, Springer Verlag, Heidelberg 1971.

[2] K. Kilian, L. Mazzone, *Hydrogen targets with very thin windows*. LEAR note 1980.