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NEUTRON PRODUCTION IN THE ENERGY RANGE 7 to 12 MeV USING A GAS-TARGET

S. Mittag, W. Pilz, D. Schmidt, D. Seeliger and T. Streil
Technical University Dresden, GDR

Presented at the IAEA Consultants' Meeting on
Neutron Source Properties, Debrecen, 17-21 March 1980

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Abstract: A gas-target for operation at a tandem-accelerator is described. Using the DD-reaction, an energy range of neutrons between 7 and 12 MeV can be realised. Construction and operation are described in detail. For neutron energies below 9 MeV the neutron source is almost monoenergetic; above this energy the deuteron break-up limits the monoenergetic behaviour.

1) Introduction

For investigation of fast neutron interactions in the energy range between 4 and 14 MeV, which cannot be covered by low-energy neutron generators, the production of a high flux of monoenergetic neutrons is necessary. These energies are important for neutron data measurements and evaluation for fast reactor and fusion reactor design.

Using a Van-de-Graaff or tandem accelerator it is possible to make accessible this energy range with sufficient intensity and small energy spread by employing the reactions D(d,n) and T(p,n) respectively. For the tandem accelerator EGP-10-1 in Rossendorf a gas-target has been developed, especially for deuterons as bombarding particles. The gas used now is deuterium, but after improvement of shielding and radiation protection system, also tritium gas should be possible for application.

2) Description of the gas-target

Fig.1 shows the construction of the target. The gas cell consists of a 0.1 mm thick stainless steal cylinder with a length of 40 mm and diameter of 9 mm. The beam-stop is a 0.2 mm thick platinum foil. Platinum is advantageous because of its small hydrogen absorption and good mechanical behaviour /1/.

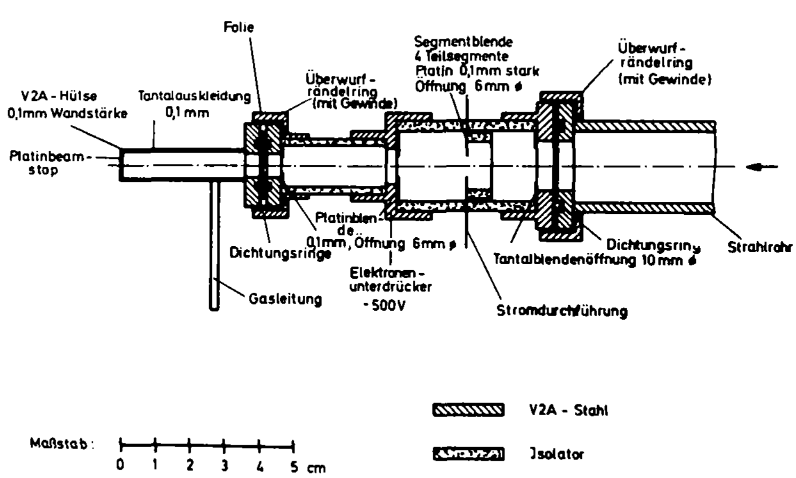

Fig. 1 Construction of the gas-target

The neutron background from such beam-stop is rather small. The entrance foil is positioned between two O-rings and two polished metal surfaces respectively. This kind of support guarantees high vacuum tightness, good thermal conductivity, elastic support against sudden pressure cut-down and gives the possibility of easy foil exchange /2-6/. A cooling of the foil is not necessary for average beam current up to 1 μA, which is the maximum value in pulsing operation of the tandem generator in Rossendorf. Under such conditions the cooling of the gas-target by air is sufficient, the diffusion of hydrogen gas through the foil is still rather small. In connection with the present investigations, foils from nickel (thickness 3.7 μm), tantalum (5.5 μm) and molybdenum (4.1 μm) have been tested.

The nickel foil gives a too high neutron background and the mechanical properties are insufficient at gas pressure higher than 1.3 at, whereas the tantalum and molybdenum foils are suitable for gas pressures up to 3 at. The molybdenum foil should be preferred with respect to a smaller gas diffusion rate and smaller energy spread.

The target cylinder is electrically insulated against the beam tube, therefore the beam current using secondary electron suppression can be measured.The electrical insulating material in all cases is PTFE. In front of the target a diaphragm is arranged, consisting of four segments to adjust and control the beam position.

3) Analysis of the emitted neutron spectra

In order to analyse neutron spectra emitted from the gas-target, time-of-flight spectra were obtained at the angle Θ_{lab} = 20° for DD-neutron energies between 7 and 12 MeV, in steps of 1 MeV. The neutron detector threshold was set to B_n = 1 MeV. Fig. 2 shows such spectra at different energies.
Besides the monoenergetic DD-neutron peak, background neutrons arise from the two following sources:

a) (d,n) reactions on construction materials and impurities of the target gas, respectively;
b) the deuteron break-up (Q = -2,227 MeV), the cross section of which increases remarkably at energies above 9 MeV.

The discrete peaks in fig. 2 , designated by numbers have been analysed and could be identified as (d,n) neutrons from carbon-12 and oxygen-16. It was shown, that these impurities not only are situated on the target materials, but also oxygen-16 is contained

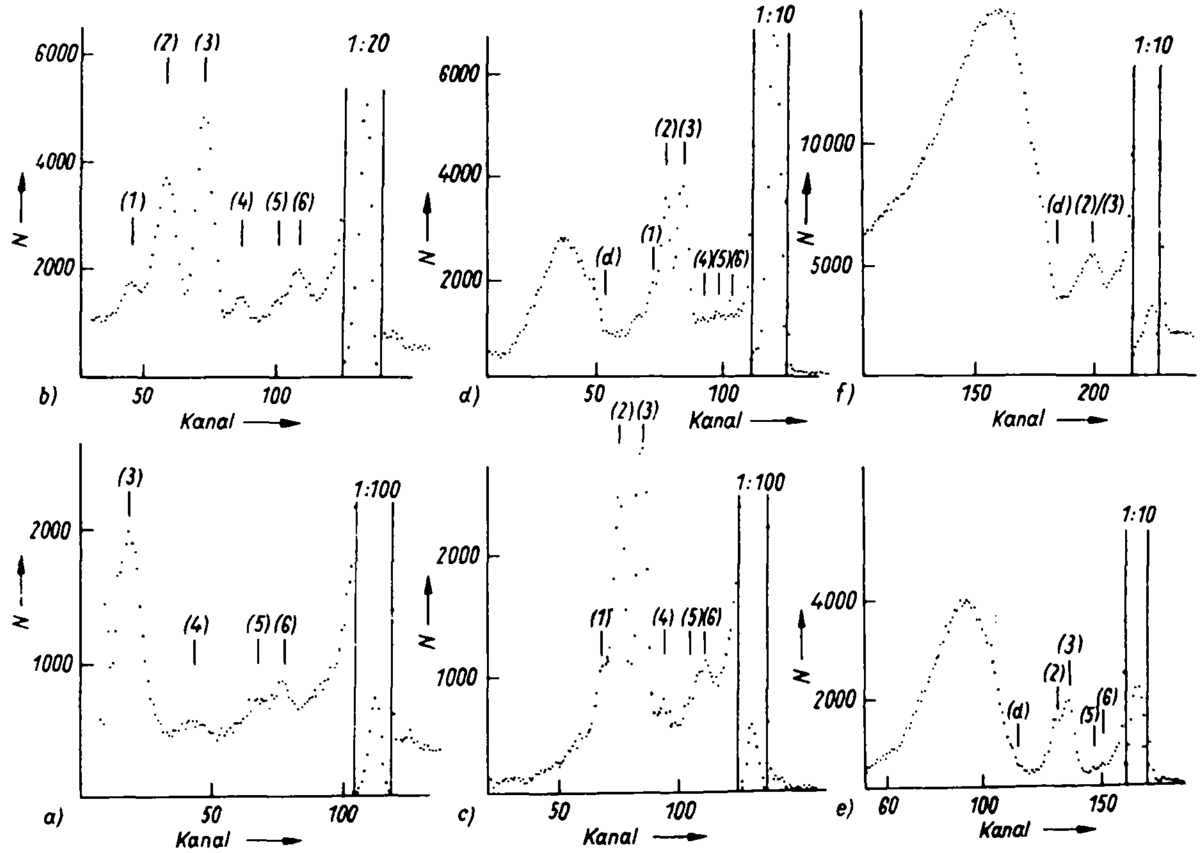

Fig. 2 Neutron time-of-flight spectra at different energies E_o (Θ_{lab} = 20°, p_{gas} = 1.3 at, foil 5.5 µm Ta); position (d) represents the highest neutron energy from the deuteron break-up /7/. a) E_o = 7 MeV; b) E_o = 8 MeV; c) E_o = 9 MeV; d) E_o = 10 MeV; e) E_o = 11 MeV; f) E_o = 12 MeV.

in the deuterium gas. This is demonstrated in fig. 3. Table 1 gives the relative number of atoms, which contribute to the background neutron lines. The numbers indicated in table 1 were obtained from

Table 1 : Relative number of nuclei of impurities related to the number of deuterons in the gas-target.

	within the gas	at the beam-stop and behind the foil	at the diaphragm and in front of the foil
oxygen-16	1:120	1:500	1:300
carbon-12		1:250	1:130

measured neutron spectra and the known cross sections for corresponding reactions.

This analysis was the reason to put into opration a nickel tube as an inlet valve. By heating of the tube only hydrogen diffuses through the nickel wall. Furthermore, it is necessary to renew the entrance foil after 350 h of operation time in order to avoid thick layers of carbon from cracking of diffusion pump oil. Another important improvement will be obtained by an oil-free vacuum system.

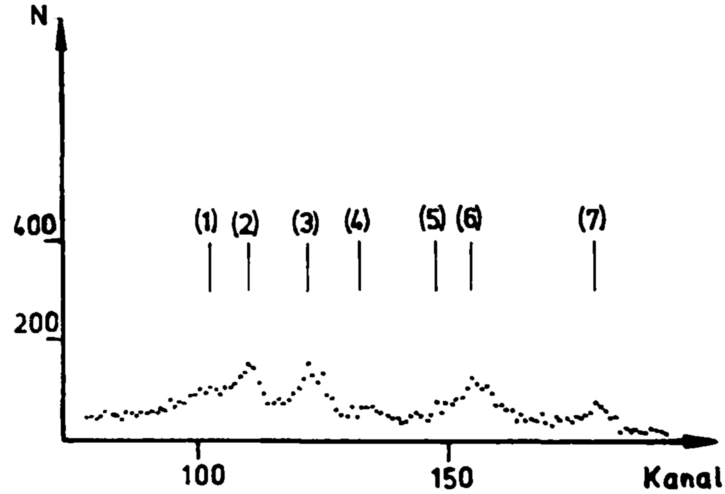

Fig. 3 Neutron time-of-flight spectrum from the target without deuterium gas; the deuteron bombarding energy corresponds to the DD-neutron energy of 8 MeV (see fig.2,b); other conditions - as indicated on fig. 2. Number (7) gives the position of the DD-neutron peak.

The relation between DD-neutrons and background-neutrons depends essentially on the emission angle. The best results concerning intensity as well as purity of the neutron beam can be obtained for the 0° angle, which therefore was chosen as the direction of the scatterer in neutron scattering experiments. Fig. 4 shows as an example a 0° angle neutron time-of-flight spectrum, which demonstrates the quality of the mono-energetic neutron line at 9 MeV.

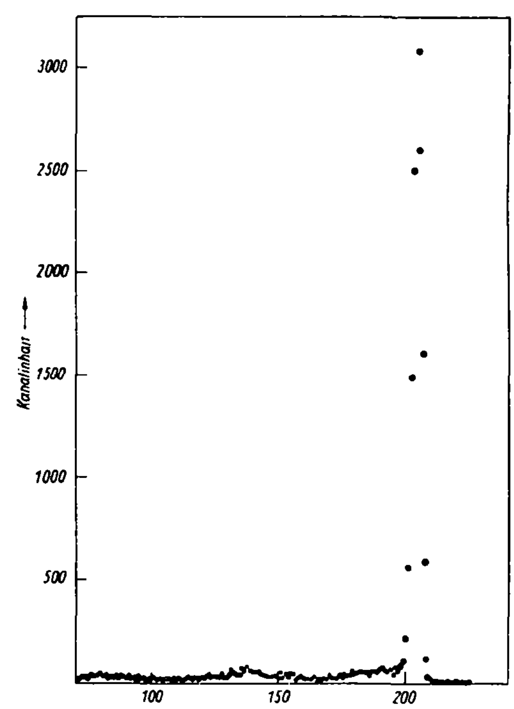

Fig.4 Spectrum for 9 MeV neutron energy (Θ_{lab} = 0°, p_{gas} = 1.0 at, entrance foil 4.1 μm Mo).

4) Results

Using a gas-target described above a neutron source is available for neutron energies from 7 up to 12 MeV. The energy spread varies approximately between 170 keV and 100 keV, and the 0°-yield is in order of 10^8 $(s \cdot sr)^{-1}$ /7/. The applicability of such source type is limited especially by the deuteron break-up. For energies of DD-neutrons higher than 9 MeV the yield of the break-up neutrons increases strongly with bombarding energy. For the 7 to 9 MeV range the source is nearly monoenergetic, the background is in the order of some percents. In connection with a multi-detector time-of-flight spectrometer /8/ this gas-target is used sucessfully for investigations of elastic and inelastic scattering of neutrons within the energy range 7 ... 12 MeV at the tandem generator EGP-10-1 in Rossendorf.

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