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THE MEASUREMENT OF THE FORMATION RATE OF pdμ MESIC MOLECULES IN GASEOUS HYDROGEN

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The formation of mesic molecules is one of the most characteristic processes, produced by negative muons in hydrogen. The knowledge of the parameters of such processes is of great interest. It is especially important in connection with the fact that the probability of the fundamental reactions of the nuclear muon capture

$$\mu^- + p \rightarrow n + \nu_\mu \quad , \tag{1}$$

$$\mu^- + d \rightarrow n + n + \nu_\mu \tag{2}$$

considerably depends upon the capture which occurs from the free state of the muonic-atom or from the muonic molecule. In particular, the knowledge of the $\lambda_{pd\mu}$ formation rate of the $pd\mu$ molecule in gaseous hydrogen is necessary both for selecting the optimal conditions and for the correct interpretation of experiments aimed at studying reaction (2) from the $d\mu$-atomic state.

Until recently the measurements of $\lambda_{pd\mu}$ were made in liquid hydrogen only. The most correct data were obtained in refs. [1,2]. The results of these measurements are presented in Table 1. In ref. [1] the value of $\lambda_{pd\mu}$ was determined by analysing the time distribution of gamma-quanta from fusion reaction (3) in the mesic molecule

$$pd\mu \longrightarrow He^3\mu + \gamma \quad (3)$$
$$pd\mu \longrightarrow He^3 + \mu^- \quad (4)$$

In the experiment[2] in order to determine the $\lambda_{pd\mu}$ value the time analysis method has been used for the mu-X radiation of neon arising in the $H_2 + D_2 + Ne$ mixture as a result of muon transfer to Ne atoms. It should be mentioned that the rates of mesic molecular processes do not always trivially depend upon the hydrogen density. (This, for instance, is proved by the results of refs.[3,4] on the measurement of the $dd\mu$ molecule formation rate in gaseous and liquid deuterium). Accordingly, we have measured the $\lambda_{pd\mu}$ value directly in gaseous hydrogen. The method for the determination of $\lambda_{pd\mu}$ was similar to that of ref.[1] and consists in the analysis of the time distribution of gamma-quanta from reaction (3).

The experiment has been performed by using the muon beam of the Dubna synchrocyclotron in the low background room. The mean energy of the muon beam was 65 MeV. The apparatus lay out is shown in Fig. 1. Muons on passing scintillation counters 1,2,3 and filter 6 hit the gas target. The method for separating muon stops in gas with CsJ(Tl) scintillators located inside the target (counters 4 and 5) has been described in ref.[5]. The target design and the system of hydrogen and deuterium purification have been described in refs.[6,7]. Gamma-quanta were detected by two counters with NaJ(Tl) crystals 150mm×100mm large electrons from the muon decay were detected with detector 5 and four stylbebe crystal scintillation counters.

The detection apparatus operated on-line with the HP-2116 computer storing information and controlling the experimental procedure.

The total of two exposures were carried out:

A - with hydrogen-deuterium mixture,

B - with pure helium (background experiment).

The conditions of these experiments are given in Table 2. The total time of exposures was 50 hours. The values describing the basic data obtained in these experiments are presented in Table 3. Figs. 2,3 show the amplitude and time distributions of gamma-quanta detected with the first detector.

The final treatment of experimental data was performed by using the BESM-6 computer. The time distribution of gamma-quanta from fusion reaction (3) after background subtraction was approximated by the following expression:

$$\frac{dn_\gamma}{dt} = A e^{-\lambda_0 t} \sum_{i=1}^{3} \frac{a_i \lambda_f c_i \left(e^{-\varphi \lambda_{pd\mu} t} - e^{-a_i \lambda_f t}\right)}{a_i \lambda_f - \varphi \lambda_{pd\mu}}, \quad (5)$$

where $a_i \lambda_f$ is the fusion rate in the $pd\mu$ mesic molecule from the spin state i ($i = 1,2,3$),

c_i is the statistical weight of the state i

φ is the ratio of gas density to liquid hydrogen density

$\lambda_0 = 0.455 \times 10^6$ I/sec is the decay rate of the free muon

λ_f is the rate of reactions (3) and (4). We used the value $\lambda_f = 0.305 \times 10^6$ I/sec obtained in the experiment[1].

Expression (5) is obtained assuming the spin-states of the $pd\mu$ mesic molecule statistically populated and taking the calculated values of a_i and c_i from ref.[8]. The above assumption proved by the results of ref.[1] on the determination of the yield of gamma-quanta from reaction (3). The obtained value of the $pd\mu$ molecule production rate in gaseous hydrogen was found to be

$$\lambda_{pd\mu} = (5.45 \pm 0.65)\times 10^{6} \ \mathrm{I/sec}$$

renormalized for the density of liquid hydrogen .

At present we are performing additional experiments to determine by an independent method the dependence of spin states of the $pd\mu$ mesic molecule and the nuclear reaction rate in this system in order to eliminate a possible uncertainty in the value of $\lambda_{pd\mu}$.

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Table I

Mesic molecule production rate

Reaction	G.Conforto et al.[2] Liquid H_2	E.Bleser et al.[1] Liquid H_2	Present paper Gaseous H_2
$d\mu + p \rightarrow pd\mu$	6.82 ± 0.25	5.8 ± 0.3	5.45 ± 0.65

Table 2

Conditions of experiments A and B

Exp.	Muon beam intensity (I/sec)	Counting rate of muon stops in gas (I/sec)	Target filling	Gas pressure in the target (atm.)
A	20 000	30	$H_2+7\%D_2$	42
B	20 000	30	He	47

Table 3

Experimental data

Exp.	Number of gamma-quanta detected at $E_{thresh.} = 4$ MeV		Number of muon stops in gas
	detector I	detector 2	
A	1550	2020	2.9×10^{6}
B	280	350	1.57×10^{6}

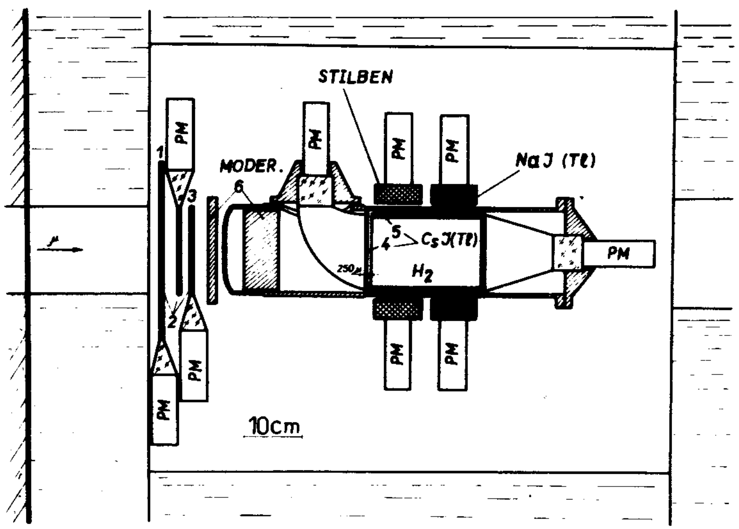

Fig.1. Schematic view of the experimental set-up (a gas target and the detectors).

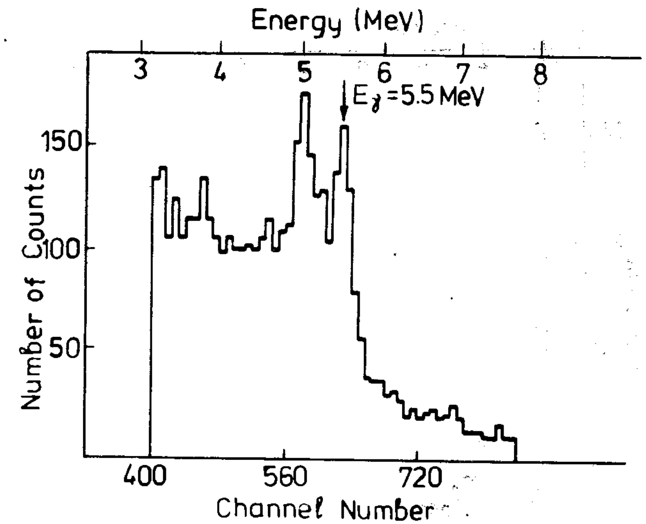

Fig. 2. Amplitude distribution of gamma-quanta in the (H_2 + D_2) experiment.

The abscissa is the gamma-quantum energy, the ordinate is the number of events per 0.092 MeV interval.

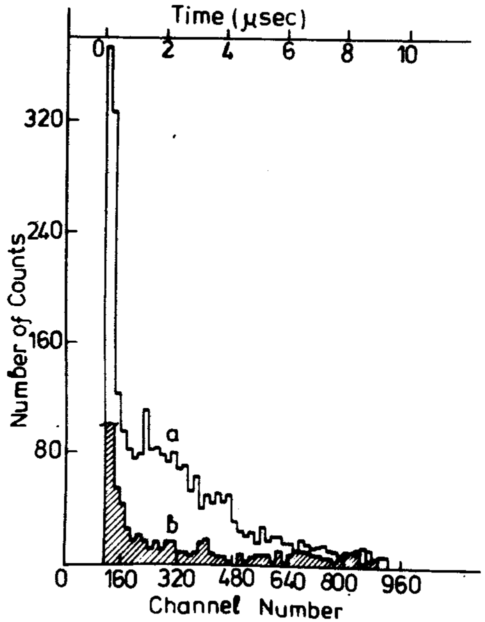

Fig. 3. Time distribution of gamma-quanta:

a) experiment with a hydrogen-deuterium mixture,

b) experiment with pure helium (dashed area in the Fig.).

The abscissa is the time measured from the moment of the muon stop, the ordinate is the number of events per 0.378 μsec.

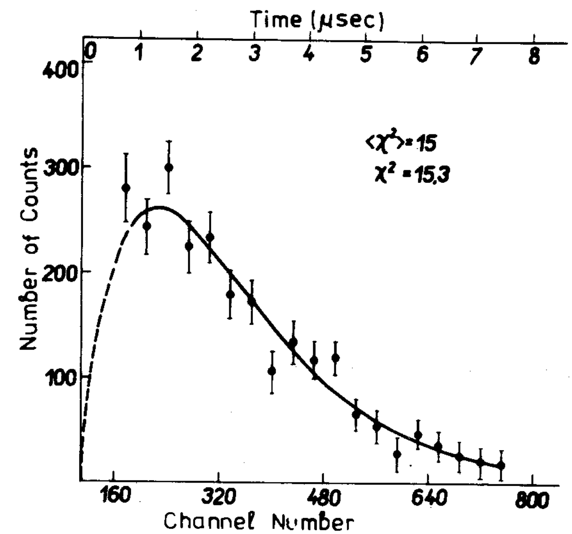

Fig. 4. Time distribution of gamma-quanta from the fusion in the mesic molecule pdμ. The normalized background has been substracted. The abscissa is the time from the moment of the muon stop, the ordinate is the number of events per 0.378 μs interval.

References

1. E.Bleser, E.Anderson, L.Lederman, S.Rosen, J.Rothberg and I.Wang. Phys.Rev., 132, 2679 (1963).
2. G.Conforto, C.Rubbia, E.Zavattini, S.Focardi. Nuovo Cim.,33,101 (1964).
3. V.M.Bystritsky, V.P.Dzhelepov, K.O.Oganesian, M.N.Omelyanenko, S.Yu.Porokhovoy, A.I.Rudenko, V.V.Filchenkov. JETP, 66,61(1974).
4. J.H.Doede. Phys.Rev., 132, 1782(1963).
5. V.M.Bystritsky, V.P.Dzhelepov, P.F.Yermolov, K.O.Oganesian, M.N.Omelyanenko, S.Yu.Porokhovoi, V.V.Filchenkov. PTE, 4,86(1971).
6. V.M.Bystritsky, V.P.Dzhelepov, P.F.Yermolov, L.S.Kotova, V.I.Lepilov, K.O.Oganesian, M.N.Omelyanenko, S.Yu.Porokhovoy, A.I.Rudenko, V.V.Filchenkov. JINR Publication 13-7246, Dubna,1973.
7. V.M.Bystritsky, V.P.Dzhelepov, N.N.Doronicheva, P.F.Yermolov, K.O.Oganesian, M.N.Omelyanenko, S.Yu.Porokhovoy, A.I.Rudenko, V.E.Teplov, V.V.Filchenkov. PTE,2, 226 (1972).
8. S.S.Gershtein. JETP, 40,698(1961).

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