Study of dμd Fusion in HD Molekules

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In previous newsletters we have presented our new precision measurements of muon catalyzed *dd* fusion in D_2 molecules showing the characteristic temperature curves of resonant $d\mu d$ formation and the effects of spin transfer [1,2]. Our collected data, however, include also observations of *$d\mu d$ fusion in HD molecules*. For these measurements we produced with a specially developed chemical apparatus a filling of almost pure HD gas (98% HD and 0.8% D_2). These data are of great interest, since the phenomena observable with HD molecules are totally different from those seen in D_2:

- There are no resonance states in the (μd + HD) system at thermal energies. It allows us to study in detail the *non-resonant* formation of $d\mu d$ molecules. While the resonant $d\mu d$ formation always leads to the P-wave *dd* fusion, the nonresonant case allows one to probe both the S- and P-wave channels of the *dd* fusion.
  The ratio $r_S = N(^3\mathrm{He}+n)/N(^3\mathrm{H}+p)$ of the two fusion channels in the S-wave is expected to be near 1.0 and was evaluated as $r_S = 0.995 \pm 0.030$. Quite contrary, in the resonant case where P-waves are involved, we found a ratio $r_P = 1.40 \pm 0.01$.

- On the other hand, the *resonant $d\mu d$* formation with much larger rates is predicted to occur in HD at epithermal energies (0.1-1 eV) of the μd atom [3]. Therefore, these resonances can only be seen in the initial time distribution of fusion events at times when the atoms are still in epithermal state ($t < 100$ ns at our conditions). We have indeed observed this effect as shown in fig 1.

The presence of the hydrogen-1 isotope in the HD gas delays the thermalisation of μd atoms due to the Ramsauer-Townsend effect (minimum of $\mu d + p$ scattering). This phenomenon enhances the effects of epithermal resonances. For a complete understanding of the resonance curve, the full energy dependent cross sections of elastic and inelastic scattering and of mesic molecule formation must be used in Monte Carlo calculations. Recently, we have performed such simulations, the result of which can also be seen in fig 1. The relative and absolute agreement with the experimental observation is remarkable, especially since no fetch factors are involved. The results obtained at higher temperatures (100 K, 150 K, 300 K) look very similar to those at 50 K.

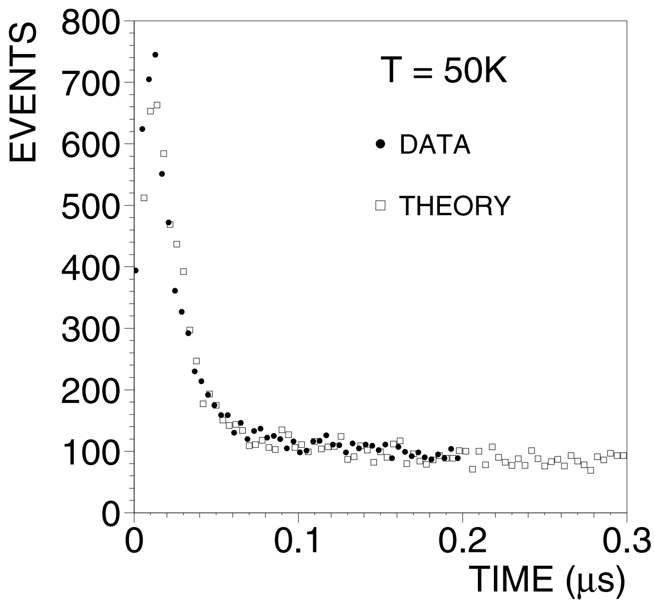

Fig. 1: Time distribution of measured fusion events ($d\mu d \to \mu +^3$ He $+ n$) in pure HD gas of density $\phi = 5\%$ at temperature $T = 50$ K (dots; background subtracted), in comparison with our Monte Carlo simulation (open squares).

References

[1] Annex I of PSI Annual Reports: 1994 (p. 43), 1995 (p. 28), and 1996 (p. 32).
[2] C. Petitjean *et al.*, Hyperfine Interactions **101/102** (1996) 1
[3] L.I. Menshikov *et al.*, Sov. Phys. JETP **65** (1987) 656, and M.P. Faifman (private communication).