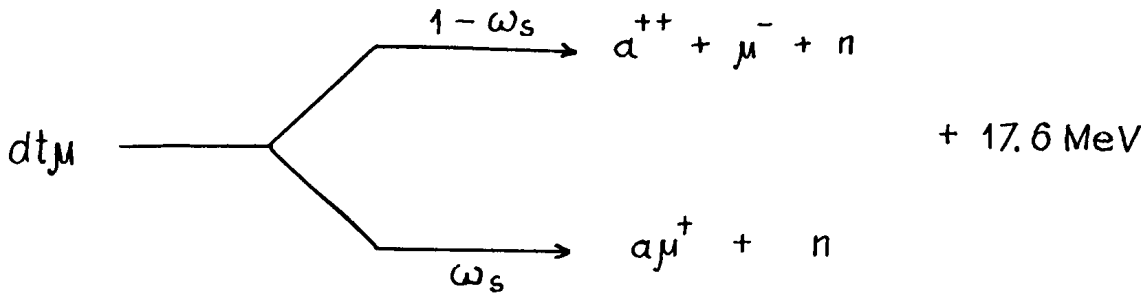
DT FUSION IN TRIPLE H/D/T GAS MIXTURE

D.V.Balin, Yu.N.Baturin, Yu.A.Chestnov, Yu.S.Grigoriev, V.S.Dubogray, A.I.Ilyin, E.M.Maev, G.E.Petrov, L.B.Petrov, G.G.Semenchuk, Yu.V.Smirenin, A.A.Vorobyov, N.I.Voropaev, C.Petitjean *, K.Lou *, P.Ackerbauer **, W.H.Breunlich **, M.Fuchs **, S.Fussy **, M.Jeitler, P.Kammel **, J.Marton*, A.Scrinzi **, J.Werner**, J.Zmeskal**, P.Baumann**, H.Bossy***, H.Daniel***, F.J.Hartmann***, R.Lipowski***, P.Wojciechowski***, K.M.Crowe****, R.H.Sherman*******

* Paul Scherrer Institute, CH-5234 Villigen, Switzerland
** Austrian Academy of sciences, A-1090 Vienna, Austria
*** Technical University of Munich, Physics Department, D-8046 Garching, FRG
**** University of California and Lawrence Berkeley Laboratory, Berkeley, CA 94720, USA
*****Los Alamos National Laboratory, Los Alamos, NM 87542, USA

In the fall of 1989 the μCF collaboration performed at the PSI-μE4 channel a 5-weeks production run with the new ionization chamber (IC) from LNPI and with a large plastic counter array to measure simultaneously alphas and neutrons of the fusion reaction



The primary goal of this experiment was to determine the sticking fraction ω_s by direct observation of both reaction channels (1).

The detailed description of the experimental layout can be found in refs. [1,2]. The 3 cm^3 sensitive volume of the IC was filled with the hydrogen triple mixture of 90% protium, 10% deuterium, and 0.05% tritium at 161 bar pressure (at 295 K) which is equivalent to 17% of liquid H_2 density. In this mixture the dt

fusion rate was 2.0% per muon, while the background of the $d\mu d$ fusion was kept at the level of ~0.4% per muon. In total, about $3 \cdot 10^6$ dt fusion events were collected during the principal runs, with 26% of the events in coincidence with the neutron counters.

During 1990, most of the data were analyzed using rather restrictive conditions in order to minimize backgrounds and to improve the spectra quality. Here are the preliminary results of this analysis.

MEASUREMENT OF DT STICKING

Figure 1 shows the resulting energy distributions of the events. Besides the big peak of fusion alphas, two tiny peaks appear at the high energy side which are due to sticking ($\alpha\mu$) and due to pile up ($\alpha\alpha$), respectively. The α and the $\alpha\mu$ events — originally both at 3.5 MeV — are located at lower but separated energies because of the charge recombination effect acting much stronger on the double charged α^{++} than on the single charged $\alpha\mu^{+}$ tracks. After correcting for rejected α events and for the remaining background, our preliminary analysis yields for sticking

$$\omega_s = 0.59\% \pm 0.07\%$$

in agreement with theory expectation 0.65% [3]. This result also agrees with a subsample containing neutron coincident events only and with the survived muon method (analysis of double fusion events), though the

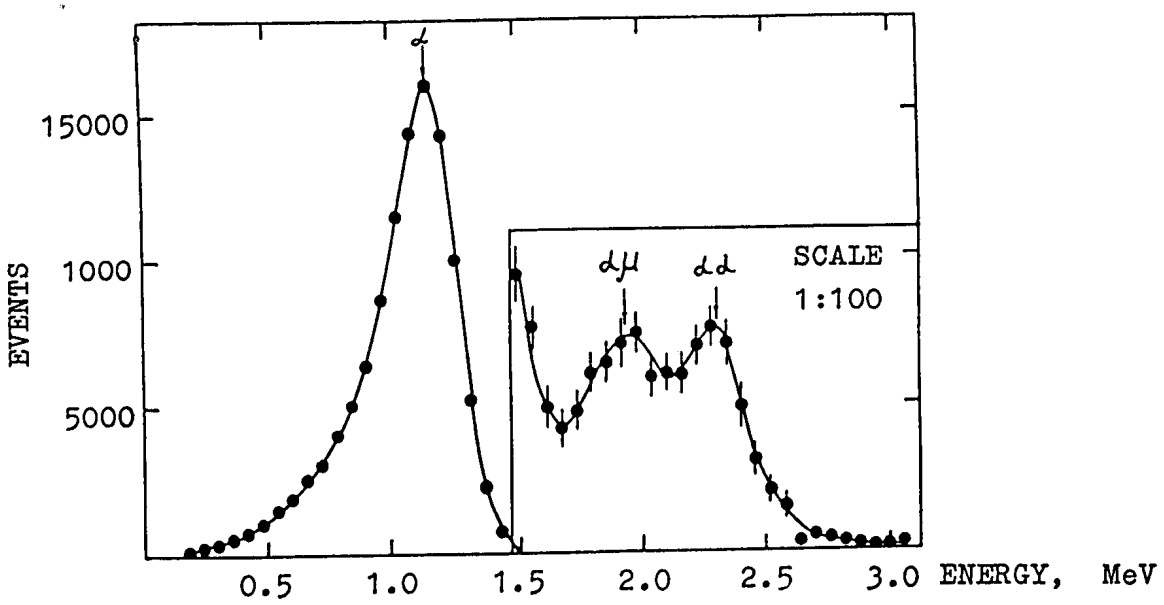


Fig.1. Energy spectrum of $d\mu t$ fusion events measured with ionization chamber. Peak $\alpha\mu$ is due to muon sticking to ^{4}He

latter analyses both have less accuracy because of lower statistics.

The unexpectedly large contribution of $\alpha\alpha$ pile up shown in figure 1 came as a surprise. It is due to rapidly succeeding second fusion events which cannot be resolved by the IC resolution of ~200 *nsec*. As it is discussed in the next section, the increased pile up probability is related with observation of a new phenomenon i.e. a very fast formation of $d\mu t$ molecule by "hot" $t\mu$ atoms.

OBSERVATION OF EPITHERMAL DT FUSION

With the help of the neutron counter timing, we have analyzed the initial time distribution of fusion events, see fig.2. A strong peak is found at times less than 100 *ns* after muon stop, contrary to our expectations (see dashed line in fig.2). This timing peak presents some interesting physics. It can be explained by direct muon transfer $p\mu \rightarrow t\mu$, followed by fast $d\mu t$ formation from hot $t\mu$ atoms on HD molecules. The hot $t\mu$ atoms pass through large reconances of $d\mu t$ formation while they get thermalized, and it follows from our analysis that most of $t\mu$ atoms produce the $d\mu t$ molecules before they are thermalized. This phenomenon is explained by slow thermalization in the H_2 environment and by extremely large cross sections for $d\mu t$ formation by epithermal $t\mu$ atoms. According to the theoretical calculations [4] $\lambda_{d\mu t}^{HD} \sim 2 \cdot 10^{10}\, s^{-1}$ at $t\mu$ energy 0.4 *eV*. In our experiment we can obtain an $\lambda_{d\mu t}^{Hd}$ value averaged over the whole energy spectrum of the epithermal $t\mu$ atoms:

$$< \lambda_{dt\mu}^{HD} >_{epl} = (6 \pm 2) \cdot 10^{9}\, s^{-1}$$

This is an order of magnitude higher than previously recorded $d\mu t$ fusion rates. This observation of

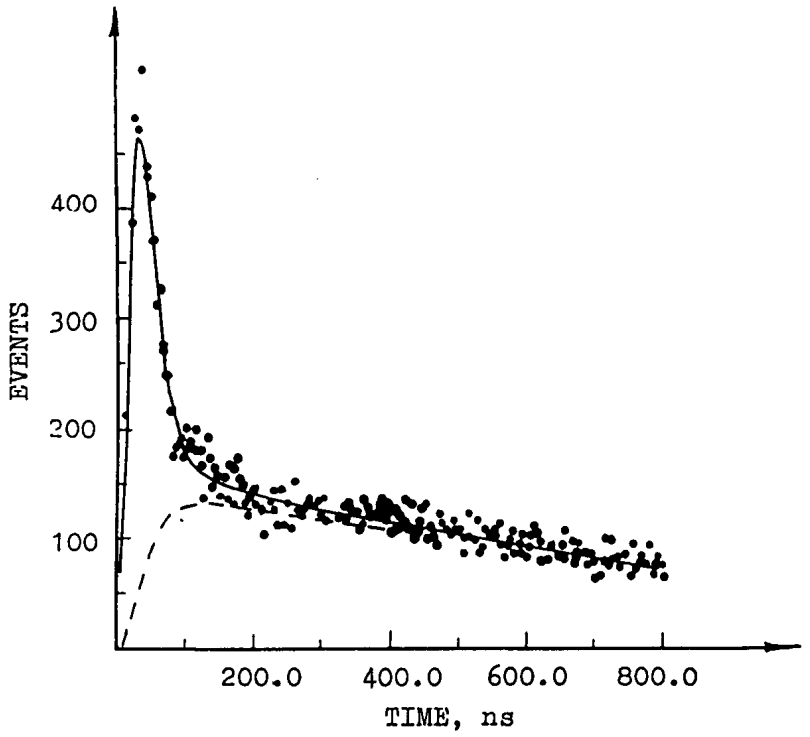


Fig.2. Time distribution of neutrons from $d\mu t$ fusion. Dashed line is an expected distribution for thermalized $t\mu$ atoms

very fast $d\mu t$ — formation rate has at least two important aspects. First, it means that the theory of DT muon catalyzed fusion, contrary to the theory of DD muon catalyzed fusion, should include into consideration not only reactions in the thermalized state of mesoatoms, $\varepsilon \sim 0.04$ *eV*, but also reactions produced by epithermal mesoatoms. Second, it opens a possibility to use the triple H/D/T mixture in the mesocatalytic reactors proposed for the energy production with the advantage that such a mixture would not require special heating to high temperatures.

This experiment will be continued in 1992 with some modification in the IC, which is aimed to increase the rate of muon stops in the IC by a factor of 4. The muon beam intensity at PSI will be also increased by a factor of 2.

References

1. Balin D.V. et al. //Muon Cat.Fusion. 5/6. 1991. 481.
2.Petitjean et al. //Muon Cat.Fusion. 5/6. 1991. 261.
3. Markushin V.E. //Muon Cat.Fusion, 3. 1988. 395.
4. Faifman M.P. et al. //Muon Cat.Fusion.4. 1989. 1.