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on Muon-Catalyzed Fusion

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CAN 250$^+$ FUSIONS PER MUON BE ACHIEVED?

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INTRODUCTION

Nuclear fusion of hydrogen isotopes can be induced by negative muons (μ) in reactions such as:

$$\underbrace{\mu^- + d + t \rightarrow \alpha + n + \mu^-}_{N} \qquad (1)$$

This reaction is analagous to the nuclear fusion reaction achieved in stars in which hydrogen isotopes (such as deuterium, d, and tritium, t) at very high temperatures first penetrate the Coulomb repulsive barrier and then fuse together to produce an alpha particle (α) and a neutron (n), releasing energy which reaches the earth as light and heat. Life in the universe depends on fusion energy.

In the case of reaction (1), the muon in general reappears after inducing fusion so that the reaction can be repeated many (N) times. Thus, the muon may serve as an effective catalyst for nuclear fusion. Muon-catalyzed fusion is unique in that it proceeds rapidly in deuterium-tritium mixtures at relatively cold temperatures, e.g. room temperature. The need for plasma temperatures to initiate fusion is overcome by the presence of the muon. In analogy to an ordinary hydrogen molecule, the muon binds together the deuteron and triton in a very small molecule. Since the muonic mass is so large, the dtμ molecule is tiny, so small that the deuteron and triton are induced to fuse together in about a picosecond - one millionth of the muon lifetime. We could speak here of muonic confinement, in lieu of the gravitational confinement found in stars, or magnetic or inertial confinement of hot plasmas favored in earth-bound attempts at imitating stellar fusion.

Room-temperature fusion is perhaps no more fantastic and no less exciting than room-temperature superconductivity. But, in both cases, questions of practicality arise. The relevant question for reaction (1) is: How many times (N) can the muon repeat or catalyze the fusion reaction during its lifetime? The answer depends on a number of factors identified in Figure 1. The diagram shows the complex chain of reactions which occur spontaneously when negative muons stop in a mixture of the hydrogen isotopes (p, d, and t) and helium (helium-4 is the product of reaction 1 while helium -3 arises from tritium decay). All of these factors have been measured at least once in recent years and are discussed in some detail elsewhere.[1-7]

Here it suffices to express the number of fusions which a muon can catalyze in dense d-t mixtures as:

$$N \simeq \left(\frac{\lambda_o}{\lambda_c^{obs}} + W\right)^{-1} \tag{2}$$

where λ_o = muon-decay rate = 0.455/μsec; λ_c^{obs} = observed muon-catalysis cycling rate, evaluated empirically as 1/(time between fusion neutrons); and W = fraction of muons lost each cycle due to capture or scavenging by helium-3 or helium-4. Equation (2) can be understood as a sum of probabilities:

$$1/\text{Yield} = \underset{\text{during catalysis cycle}}{\text{Probablility of muon decay}} + \underset{\text{by } ^3\text{He or } ^4\text{He}}{\text{Probability of muon capture}} \tag{3}$$

In order to make N as large as possible, it is clear from the yield equation (2) that one must maximize λ_c and minimize W. It is the purpose of this paper to describe what we have learned about achieving these ends, and then to estimate yields anticipated during forthcoming LAMPF experiments. It will be shown that based on previous LAMPF results, we expect to exceed 250 fusions per muon, although such high yields are impossible if results from SIN experiments are taken at face value. The significance of achieving 250 fusions per muon for possible energy applications of muon-catalyzed fusion will also be explored.

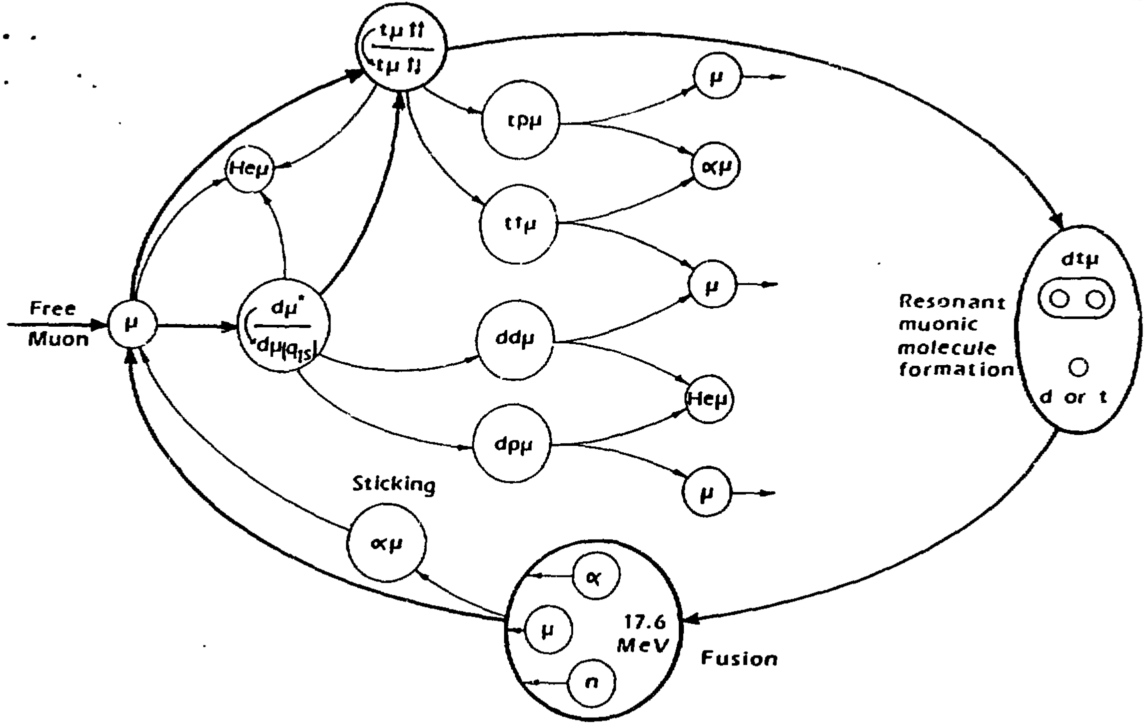

Figure 1. Muon catalysis cycle, showing reactions which occur when negative muons(μ) stop in a mixture of the hydrogen isotopes (p,d,t) and helium (He or α).

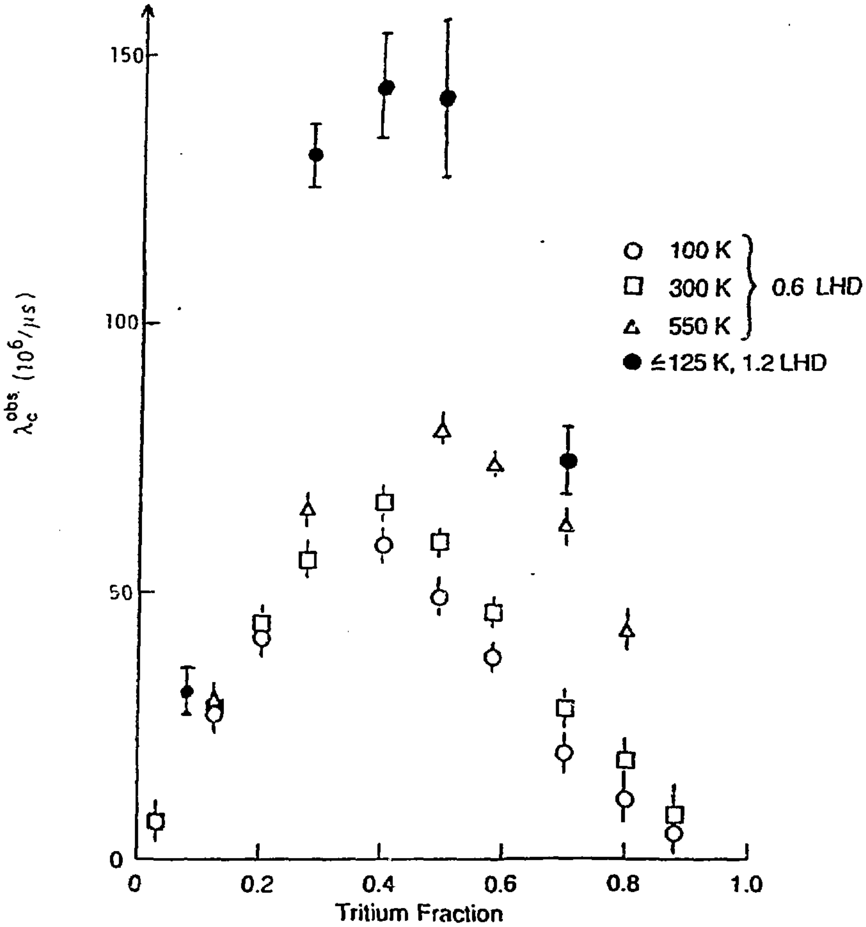

Figure 2. Dependence of the observed muon catalysis cycling rate on tritum fraction, temperature and density.

Observed cycling rates measured at LAMPF[4,6] are summarized in Figure 2. An example of the high-pressure (up to 1000 atm) target flasks used for the LAMPF experiments since 1982 to obtain these data is provided in Figure 3. The data demonstrate clearly that muon catalysis proceeds more rapidly as one increases either the temperature or density of the deuterium-tritium target mixture. In order to assess the physical processes which are responsible for these observed effects, we must sort out and measure the underlying reactions depicted in Figure 1. Salient features of the reaction kinetics can be succinctly stated:

$$\frac{\phi}{\lambda_c^{obs}} \approx \frac{C_d}{(\lambda_{dt/q_{1s}})C_t} + \frac{1}{\lambda_{dt\mu}C_d} \qquad (4)$$

where λ_c^{obs} = observed muon-catalyzed fusion cycling rate (see equation 2);

ϕ = deuterium-tritium mixture density relative to liquid-hydrogen density (LHD = 4.25×10^{22} atoms/cm^3);

C_d, C_t = fractions of deuterium and tritium, respectively: $C_d + C_t = 1$;

$\lambda_{dt/q_{1s}}$ = rate of the muon-transfer reaction $d\mu + t \rightarrow t\mu + d$ (The factor q_{1s} will deviate from unity both because of muon transfer to t from excited states of dμ,[8] and because the initial atomic capture ratio might differ somewhat from the ratio C_d/C_t.)

$\lambda_{dt\mu}$ = the rate of resonant formation of dtμ molecules in collisions of tμ atoms with D_2 or DT molecules (see Figure 1).

It is worthwhile to summarize what we have learned about the rates which determine the overall cycling rate:[6]

$$\lambda_{dt} \approx [1 + (6 \pm 1) \times 10^{-4}T]\ (280 \pm 40) \times 10^6\ s^{-1} \qquad (5)$$

for the temperature range 20-500 K (observed λ_{dt} varies approximately linearly with density). This value of λ_{dt} agrees with the low - ϕ, low-C_t experiment of Bystritsky et al.[3] The temperature dependence is not quite as strong as predicted[9] but shows the same trend.

$$q_{1s} \approx [1-(1-\gamma)\ C_t]\ \gamma^{2C_t},\ \gamma = (0.75 \pm 0.2). \qquad (6)$$

The q_{1s} factor has been the subject of extensive experimental[6,7] and theoretical[8] study, and we are currently analyzing new data in which we

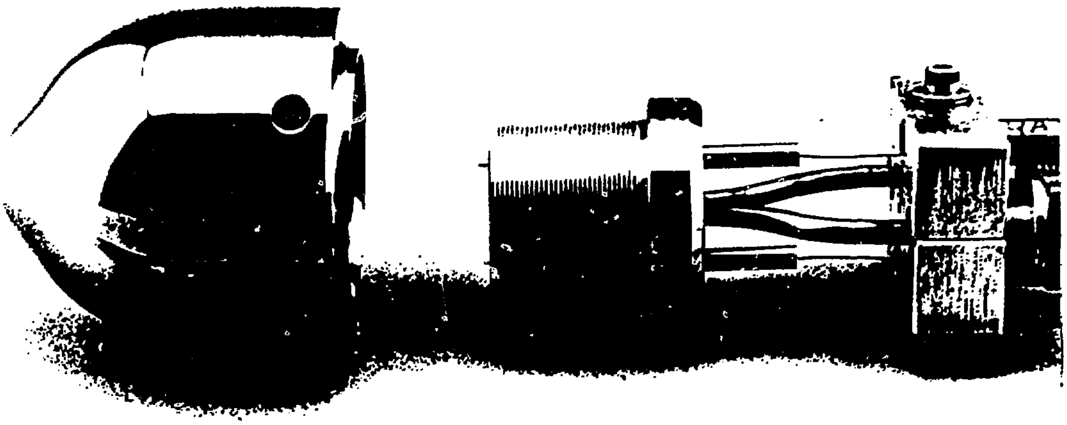

Figure 3. Target capsule built at the Idaho Natioanal Engineering laboratory for muon-catalyzed fusion research at LAMPF. This second-generation capsule is used for temperatures in the range $18K < T < 800$ K and pressures up to 1000 atm.

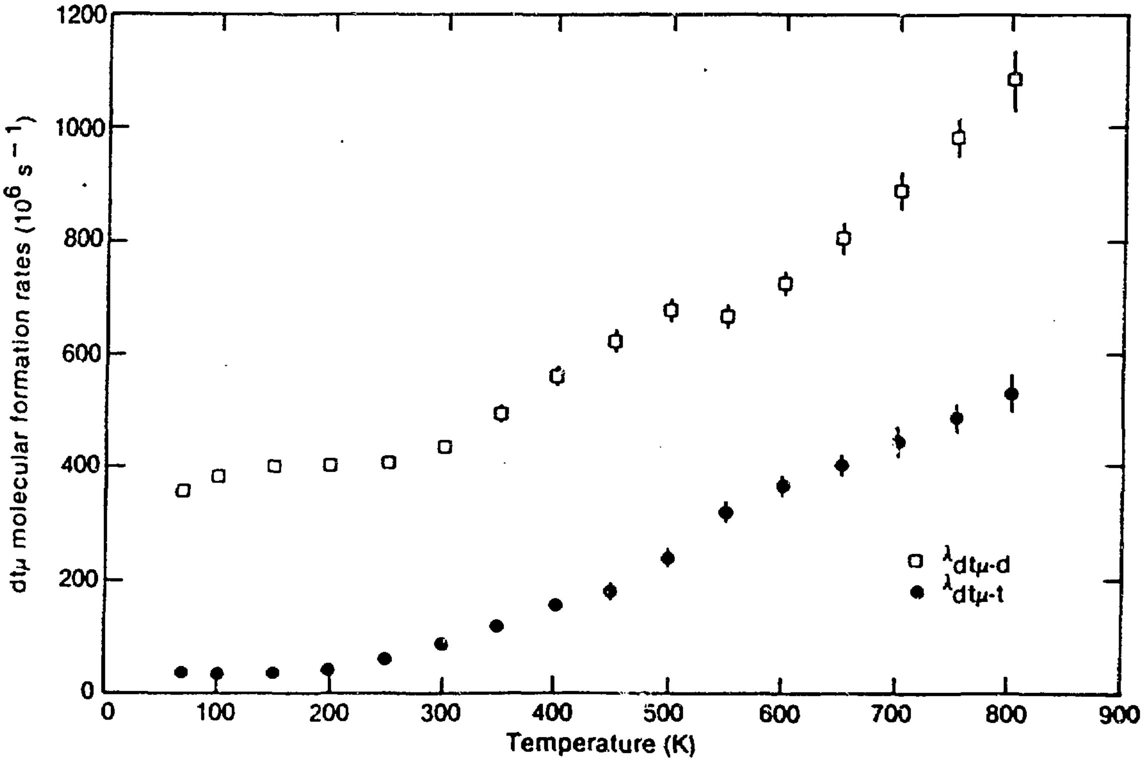

Figure 4. Resonant dtμ-molecular formation rates $\lambda_{dt\mu-d}$ and $\lambda_{dt\mu-t}$ for (tμ + D_2) collisions and (tμ + DT) collisions, respectively.

explore the ϕ - and C_t - dependencies of q_{1s} in detail. But the empirical expression above (from Ref. 6) is adequate for present purposes.

The empirical relations (5) and (6) show that the dμ to tμ muon transfer rate (λ_{dt}/q_{1s}) is relatively insensitive to variations in density or temperature. Yet the observed cycling rate clearly depends strongly on these experimental conditions (see Fig. 2). Thus, from equation (4) we must conclude that it is the dtμ-formation rate that increases strongly with increasing temperature and density. These results are displayed quantitatively in Figures 4 and 5.

Figure 4 displays a number of surprises uncovered by the LAMPF experiments. First, there are two distinct dtμ-formation ratios, $\lambda_{dt\mu-d}$ and $\lambda_{dt\mu-t}$, corresponding to collisions of tμ atoms with D_2 and DT molecules, respectively, so that

$$\lambda_{dt\mu} = C_d\, \lambda_{dt\mu-d} + C_t\, \lambda_{dt\mu-t} \qquad (7)$$

Both of these dtμ - formation rates are seen to be resonant,[10] in that the rates are very large (~ 3 orders of magnitude larger than expected for non-resonant Auger reactions) and show a strong dependence on temperature. It is interesting to note that our observation of a strong-temperature dependence of dtμ-formation rates was initially challenged. At an earlier school held at Erice in 1984, W. Breunlich et al. reported[11] that "dμt formation rates, on the other hand, only show weak temperature dependence," in direct contradiction of our published results [see also ref. 5]. However, a recent paper by W. Breunlich et al.[12] now reports a strong temperature dependence, at least for $\lambda_{dt\mu-t}$, confirming the LAMPF result. Both groups now concur that $\lambda_{dt\mu-t}$ has the expected property of approaching zero as $T \to 0$ (Figure 4).

On the other hand, $\lambda_{dt\mu-d}$ is rather constant for $T < 300K$. This striking behavior was disturbing when first discovered in the research at LAMPF, but since has been explained in context of the resonant dtμ formation model by Yuri Petrov.[13] A beneficial consequence of this unexpected effect is that high cycling rates (λ_c^{obs}) can be realized even at low temperatures. This explains in part why yields of well over 100 funsions per muon could be achieved at LAMPF in 1984[6] even in liquid deuterium-tritium mixtures at 20K. This result has since been reproduced in experiments at SIN (Switzerland)[7] and KEK (Japan).[14]

That $\lambda_{dt\mu-d} >> \lambda_{dt\mu-t}$ for $T < 100K$ was proven directly at LAMPF in 1984 [see footnote 16, ref. 6]. This was accomplished by keeping a C_t =

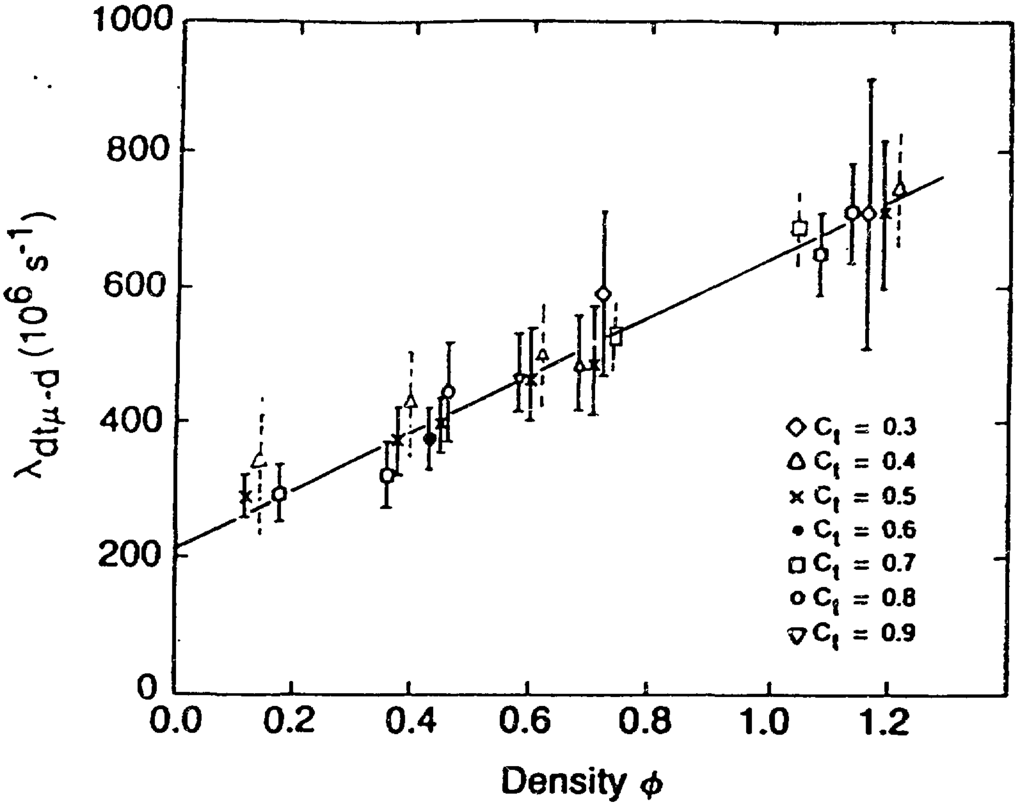

Figure 5. Density dependence of the normalized dtμ-molecular formation rate for ($t\mu + D_2$) collisions observed at LAMPF. Preliminary results from August 1986 runs are displayed with dashed error bars.

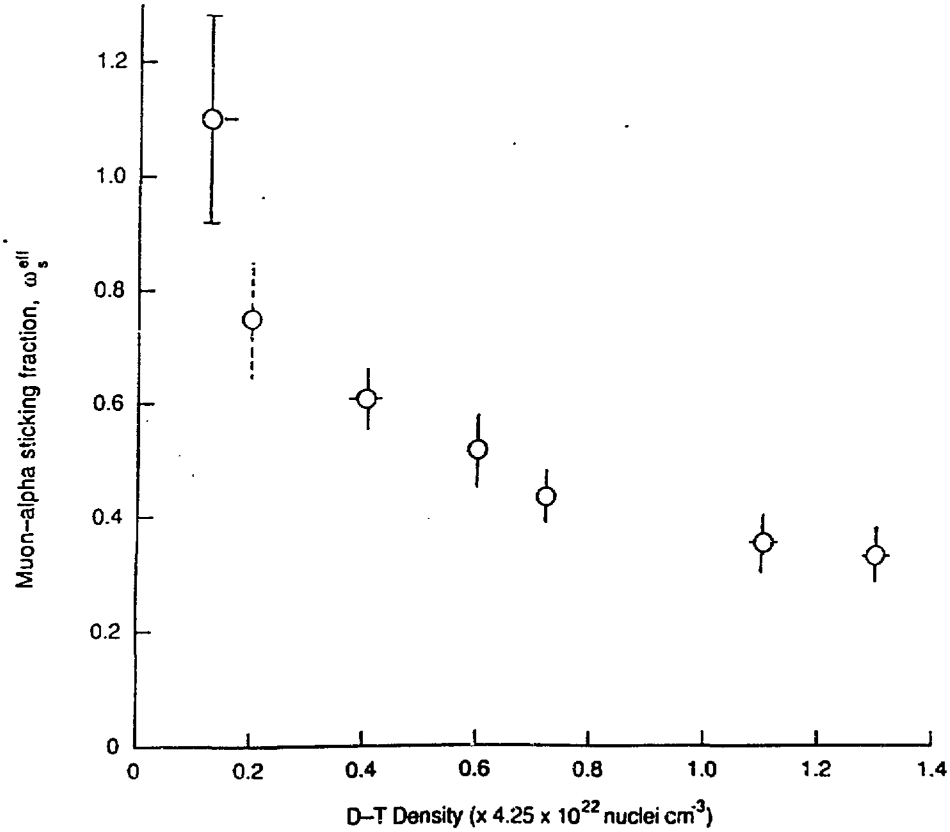

Figure 6. Dependence of ω_s^{eff} on deuterium-tritium density based on data acquired at LAMPF, 1982-1986. Preliminary result from August 1986 run is shown with dashed error bars.

0.7 mixture liquefied at T < 30K for 30 hours. We observed a slow rise in λ_c over the course of the experiment. When the D_2-DT-T_2 mixture was first liquefied, relative molecular concentrations were approximately:

$$C_{D_2} : C_{DT} : C_{T_2} = C_d^{\,2} : 2C_dC_t : C_t^2, \tag{8}$$

representing high-temperature equilibrium ratios. As expected, the equilibrium slowly evolved at cold temperature to favor (D_2 + T_2) at the expense of DT. Then the cycling rate increased, showing directly that (tμ + D_2) collisions yield dtμ-molecules much more rapidly than do (tμ + DT) collisions; i.e., $\lambda_{dt\mu-d} \gg \lambda_{dt\mu-t}$ at low temperatures in keeping with Figure 4. This result has also been confirmed at SIN.[7] The results imply that a liquid (D_2 + T_2) mixture can be prepared and maintained at cold temperatures, and that cycling rates will be much higher than in (D_2 + DT + T_2) mixtures. This means of enhancing λ_c is more difficult to accomplish at higher temperatures since then the (D_2 + T_2) mixture would quickly equilibrate according to relation (8), evolving DT at the expense of D_2.

Figure 5 suggests yet another reason for prefering cold (D_2 + T_2) mixtures at high densities: $\lambda_{dt\mu-d}$ increases rapidly with increasing density, thus enhancing λ_c. Interestingly we find no such strong density dependence for $\lambda_{dt\mu-t}$.[6] These LAMPF results have been confirmed qualitatively at SIN, but the density-dependence of $\lambda_{dt\mu-d}$ is weaker.[7] However, data taken at LAMPF in August 1986 (dashed bars in Figure 5) agree very well with our previously published results.[6]

The striking density-dependence of $\lambda_{dt\mu-d}$ [Figure 5] provides evidence of significant resonant dtμ formation via three-body collisions. Menshikov and Ponomarev[15] have discussed a mechanism for three-body resonant molecular formation, e.g., $t\mu + D_2 + D_2 \rightarrow [(dt\mu)\ d2e]^* + D_2 + \Delta E$. The singlet (tμ+ D_2) collisions are special in having their strongest resonances just below threshold, where they are not accessible in two-body collisions. By absorbing some kinetic energy, the spectator molecule (D_2, DT, or T_2) moves these strong resonances above threshold, allowing them to contribute to very rapid dtμ molecular formation.

There exist theoretical predictions[13] that $\lambda_{dt\mu-d}$ and therefore λ_c must saturate and level off at sufficiently high densities. Indeed, we have reported such an effect at high temperatures (T $\geq$ 450K).[16] But no saturation in $\lambda_{dt\mu-d}$ (or λ_c) is yet seen for densities up to 1.3 liquid-hydrogen density (LHD) for T < 200K.

In summary, a cold (D_2 + T_2) target at high density will allow us to achieve very fast muon-catalysis cycling rates. Since $\lambda_{dt\mu-d}$ is large for these conditions, such a target will provide much larger cycling rates than, for instance, a high-temperature ($T > 800K$) target, although high temperatures are very interesting in their own right. Engineering constraints also limit the densities which can be achieved at high temperatures.

Consider, then a ($D_2 + T_2$) mixture at ~30K, compressed to a density of approximately 2.3 LHD (nearly twice the density now achieved at LAMPF, SIN or KEK). The optimum tritium fraction for D_2-DT-T_2 at high temperature equilibrium is $C_t \sim$ 30-40% (Figure 2). Using ($D_2 + T_2$), we can increase λ_c by moving to higher C_t (~ 50%) so as to increase $\lambda_{dt/q_{1s}}$. Based on an extrapolation of the LAMPF results described above (assuming no saturation of $\lambda_{dt\mu-d}$ at high density), we would then expect for these conditions:

$$\lambda_c^{obs} \approx 7 \times 10^{-4} \ s^{-1} \ \text{(extrapolation)} \tag{9}$$

It is useful to look at the fusion yield which this rate would produce if W were zero (see equation 1):

$$N_{W=0} = \frac{\lambda_c^{obs}}{\lambda_o} \approx 1500 \ \text{fusions}/\mu- \quad \text{(extrapolation)} \tag{10}$$

Thus, it is clearly possible to achieve well over 250 fusions per muon based on what we have learned about increasing the muon-catalysis reaction rates. This result is a clear departure from theoretical predictions of slow cycling rates expected just ten years ago, and is an exciting confirmation of the resonance model of dtμ-formation developed by S.S. Gershtein, L.I. Ponomarev and their co-workers.[10,15,19]

We are in fact preparing to perform a set of experiments with these ultra-high-density conditions at LAMPF in 1987. Before further discussing the new experiments, however, it is important to turn our attention to the muon-loss factor W which is now expected to limit the achievable number of fusions per muon.

MINIMIZING HELIUM CAPTURE LOSSES

Figure 1 illustrates many ways in which the muon may be lost from the muon catalysis cycle. Each of these results in muon capture by a helium nucleus and contributes to the muon-loss probability W (see equations 1,2). The muon may be captured and retained by a helium nucleus synthesized during dtμ, ddμ, or ttμ fusion, with sticking probabilities ω_s, ω_d, and ω_t, respectively. In addition, small amounts of protium may be present resulting in $pd\mu$ and $pt\mu$ fusion, with sticking probabilities ω_{pd} and ω_{pt}. The muon may also be scavenged by ^{3}He introduced by tritium decay (normally $C_{He} < < 1\%$). The total muon loss probability per cycle can be written as[4,6,7]

$$W \simeq \frac{q_{1s} C_d}{\lambda_{dt} C_t + \lambda_{dd\mu} C_d} (0.58 \lambda_{dd\mu} C_d \omega_d + \lambda_{pd\mu} C_p \omega_{pd} + \lambda_{dHe} C_{He}) \qquad (11)$$

$$+ \frac{1}{\lambda_{dt\mu} C_d} (\lambda_{tt\mu} C_t \omega_t + \lambda_{pt\mu} C_p \omega_{pt} + \lambda_{tHe} C_{He}) + C_{He} \omega_{He} + \omega_s^{eff},$$

where $\lambda_{dt\mu}$, $\lambda_{dd\mu}$, $\lambda_{tt\mu}$, $\lambda_{pd\mu}$, $\lambda_{pt\mu}$ are the rates for $dt\mu$, $dd\mu$, $tt\mu$, $pd\mu$ and $pt\mu$ molecular formation, λ_{dHe} and λ_{tHe} are the rates for transfer to ^{3}He from the $d\mu$ and $t\mu$ ground states, and ω_{He} is the probability for initial capture by ^{3}He. ω_s^{eff} is then the effective sticking probability following $dt\mu$-fusion. Note that it is possible that some other correction term remains to be included in equation (11), in which case $\omega_s < \omega_s^{eff}$.

Now, for the proposed high-density experiment, we will assure very small protium and helium contaminations. Thus, all terms involving C_p and C_{He} will become negligible. Most other terms also become small since (λ_{dt}/q_{1s}) and $\lambda_{dt\mu}$ become large. For example, while $\lambda_{tt\mu}$ scales linearly with density, $\lambda_{dt\mu}$ increases much faster than this (see Figure 5), so that losses following $tt\mu$-fusion become smaller as one elevates the target density. Consequently, for the conditions of our new experiment, although small correction terms will not be neglected, $W \approx \omega_s^{eff}$, and equation 11 reduces to:

$$N \cong \left(\frac{\lambda_o}{\lambda_c} + \omega_s^{eff}\right)^{-1} . \qquad (12)$$

We have shown that λ_c can become very large at high densities. What happens to ω_s^{eff}?

A strong dependence of ω_s^{eff} on target density is suggested by all the data acquired at LAMPF since 1982, shown in Figure 6. We have acquired data over a broad density range, $0.12 < \phi < 1.4$ in small steps, and find that ω_s^{eff} decreases with increasing density over this range.

At first, we thought that this effect might be due to impurities (methane, water, etc.) in the D-T mixture, so we did the following test. We filled carefully cleaned target flasks at low density ($\phi < 0.4$) and very low impurity concentration and measured sticking losses in the gas at ~ 50 K. At this temperature, only hydrogen (and any helium) should remain in the gas phase. Then we cooled the <u>same</u> targets to ~ 30 K, so as to liquefy the hydrogen, and re-measured the sticking friction. Each time we found a consistent drop in ω_s^{eff} as the target gas liquefied and the density increased.

The LAMPF experiments point to a significant decrease of ω_s^{eff} with increasing density (Figure 6). A recent paper by Breunlich et al. strongly contradicts this observation.[7] But one cannot be terribly disturbed by this latest disagreement. After all, the LAMPF result that $\omega_s^{eff} \approx 0.4\%$ at high densities was also controversial when first presented at the Jackson Hole Workshop in 1984.[17] However, experiments at both SIN and KEK have now quantitatively confirmed (within errors) this surprising result.[7,14]

It is only at low densities that the LAMPF and SIN results diverge. But for these conditions, cycling rates are small making an accurate evaluation of ω_s^{eff} difficult.[16] We can hope to resolve this sticky issue by doing experiments at very high densities, up to 2.3 LHD, for then the sticking fraction becomes quite easy to measure (equation 12). We have seen too many surprises in this research to suppose that we can resolve the issue by theoretical discussion alone, without dedicated experiments. Both the magnitude and density dependence of ω_s^{eff} must be settled experimentally.

Therefore, we welcome the many experiments in the United Kingdom, Japan and the Soviet Union as well as in Switzerland and the United States, which seek to provide further insight regarding the α-μ sticking fraction. After all this quantity represents the primary bottleneck to achieving high yields with muon-catalyzed fusion.

Figure 7 displays the approximate number of d-t fusions per muon which might be expected in the new LAMPF experiment at 2.3 LHD, based on equations (9) and (12), and boldly extrapolating the LAMPF results for ω_s^{eff} (Figure 6) to $\phi = 2.3$. In conclusion, we expect to exceed 250 fusions/muon in LAMPF experiments later this year. Note that if $\omega_s \simeq 0.45\%$, as might be expected from SIN results,[7] then the maximum yield according to equation 12 would be $N < \frac{1}{\omega_s} \approx 220$ fusion/muons. "Se son rose fioriranno" ("if it is a rose, it will bloom").[1]

THE SIGNIFICANCE OF ACHIEVING 250+ FUSIONS PER MUON

For many years, it was thought that muon-catalyzed fusion would be limited to about one fusion per muon. Slow mesomolecular (i.e., dtμ) formation was seen as the limiting factor:

> "The present analysis shows that capture of muons by helium nuclei has no relevance to the question of achieving chain reactions since mesomolecular formation rates limit the number of catalyzed reactions to an average one per muon. Since only

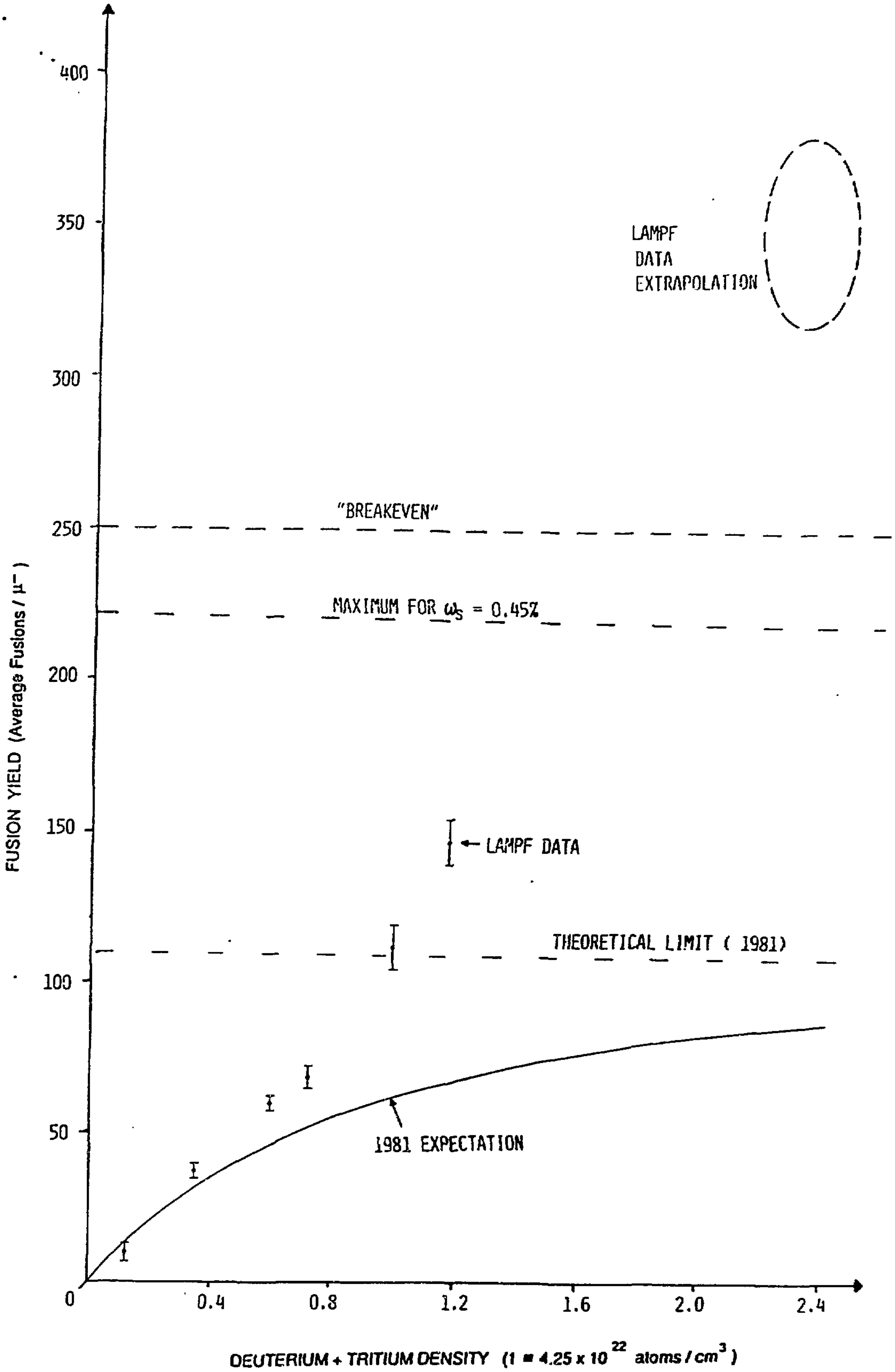

Figure 7. Observed and anticipated muon-catalyzed fusion yields as a function of density. Data acquired at LAMPF for cold (T < 100K) equimolar D_2-DT-T_2 mixtures exceed 1981 predictions. Extrapolating from LAMPF results, a new experiment for cold D_2 + T_2 mixtures at 2.3 LHD should exceed even the "energy breakeven" level described in the text.

one catalyzed reaction per muon can be expected, muon catalysis of fusion reactions falls far short of energy balance."[18]

The subject was revived by a series of important Soviet studies beginning in 1977.[10,19] In their 1977 paper outlining resonant dtμ-molecule formation, S.S. Gerstein and L.I. Ponomarev revive also the possibility of energy production by muon-catalysis:

> "It means that every μ- meson in the mixture [of] deuterium and tritium can produce ~10^2 of the nuclear fusion reaction and release ~2 GeV which is 20 times the rest mass of [the] muon."[a]
>
> "We leave the question open about the possibilities of practical applications of the phenomenon discovered (e.g., the production of energy in fusion reactors, the breeding of tritium by ejected neutrons in the mixture of ^{6}Li and ^{7}Li, the ignition of the thermonuclear fusion reaction provided by lasers, etc.), Nevertheless, we would like to call attention to it."[10]

Then in 1980, Yu. Petrov presented a clever scheme for a power reactor based on muon-catalyzed fusion combined with nuclear fusion processes.[20] He showed that a commercial hybrid reactor would require only about 100 fusions per muon. Subsequent studies have also concluded that 100-200 fusions per muon would suffice for a fusion/fission hybrid power plant.[21,22] It is interesting to note that in the 1979 school on exotic atoms at Erice, J. Rafelski predicted that it might be possible to achieve 100-200 fusions per muon.[23]

In 1984, yields of 150 fusions per muon were in fact realized at LAMPF[6] invigorating speculations regarding pratical applications for muon-catalyzed fusion. Later experiments at SIN[7] and KEK[14] have achieved similar yields.

Are we approaching a limit, or can significantly higher fusion yields be expected? As shown in this paper, muon catalysis cycling rates can be made extremely fast (equations 9, 10), thanks to resonant dtμ-formation. Thus, we find that the limiting factor to muon-catalyzed fusion in fact

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a). This provides a reasonable definition of "scientific breakeven" for muon-catalyzed fusion. In experiments at LAMPF, SIN and KEK, the fusion yields now exceed the energy of the fusion reaction initiator, ignoring muon production inefficiencies, by an order of magnitude.

stems from muon losses due to alpha-sticking (ω_s).

Prior to the LAMPF experiments, it was calculated that $\omega_s \approx 0.9\%$, so that the yield would be limited to ~110 fusions per muon.[1] Now that this "barrier" has been surpassed (see Fig. 6), it becomes an open question how many fusions per muon can be achieved. The new LAMPF experiment addresses this question, using the best information we now have regarding how to make λ_c large and W small.

I might draw a parallel with recent breakthroughs in superconductivity research. Now that the barrier of attaining superconductivity at 77K (boiling temperature of liquid nitrogen) has been surpassed,[24] room-temperature superconductivity is easily imaginable, and possible applications become enthusiastically discussed.

Similarly, 250 fusions per muon would be significant because it represents an "energy breakeven" level for muon-catalyzed fusion. A number of studies suggest that approximately 5000 MeV of energy must be invested to produce one negative muon by state-of-the-art techniques.[20-22,24] Each muon-induced fusion reaction would produce about 20 MeV, taking credit for the energy released in producing tritium from lithium. Then "breakeven" would require approximately:

$$N_b = \frac{E_{in}}{E_{out}} \approx \frac{5000\ \text{MeV/muon}}{20\ \text{MeV/fusion}} = 250\ \text{fusions/muon.} \qquad (11)$$

Thus, reaching 250 fusions/muon would be interesting from a practical standpoint.

Finally, I would submit that the feasibility of producing electrical power by means of muon-catalyzed fusion ought to be re-examined in view of the recent discovery[24] of high-temperature superconductivity. A scheme like Petrov's[20] is actually a power multiplier: input power is fed to an accelerator which generates muons which in turn induce fusion reactions. Fusion energy is then converted to electrical power, much of which must be recirculated to drive the accelerator. But with inexpensive superconductivity all energy conversion processes become much more efficient making a power multiplier more attractive. A muon-catalyzed fusion reactor with superconducting rf sources, accelerator wave-guides and generators would be fascinating to study. In addition to having high efficiency, the accelerator ought also to be shorter and involve less capital expenditures. These factors are particularly relevant to muon-catalyzed fusion schemes where considerable recirculating power is required.

NEW LAMPF EXPERIMENT AT 2.3 LHD

We have considered multiple motivations for studying muon-catalyzed fusions using (D_2 + T_2) mixtures at high densities. We are limited to cold temperatures and ~2.3 LHD for practical reasons: static pressures for these conditions approach 10 kbars. Our goal is to explore (static) high-density limits of muon-catalyzed fusion. An increased understanding of the process in this regime may enhance our ability to achieve high fusion yields with lesser engineering challenges.

The target flasks for this new experiment are being designed and built at the Idaho National Engineering Laboratory under the direction of Dr. A.J. Caffrey. Figure 8 shows a preliminary design of our new target capsule which is actually the fifth generation of target flasks used at LAMPF since 1982. The recessed ports facilitate muon entry and muon-decay electron egress from the D_2-T_2 bearing chamber where fusion occurs. We expect to perform the experiments at LAMPF later in 1987. Thus, we will soon find out whether 250^+ fusions per muon can be achieved.

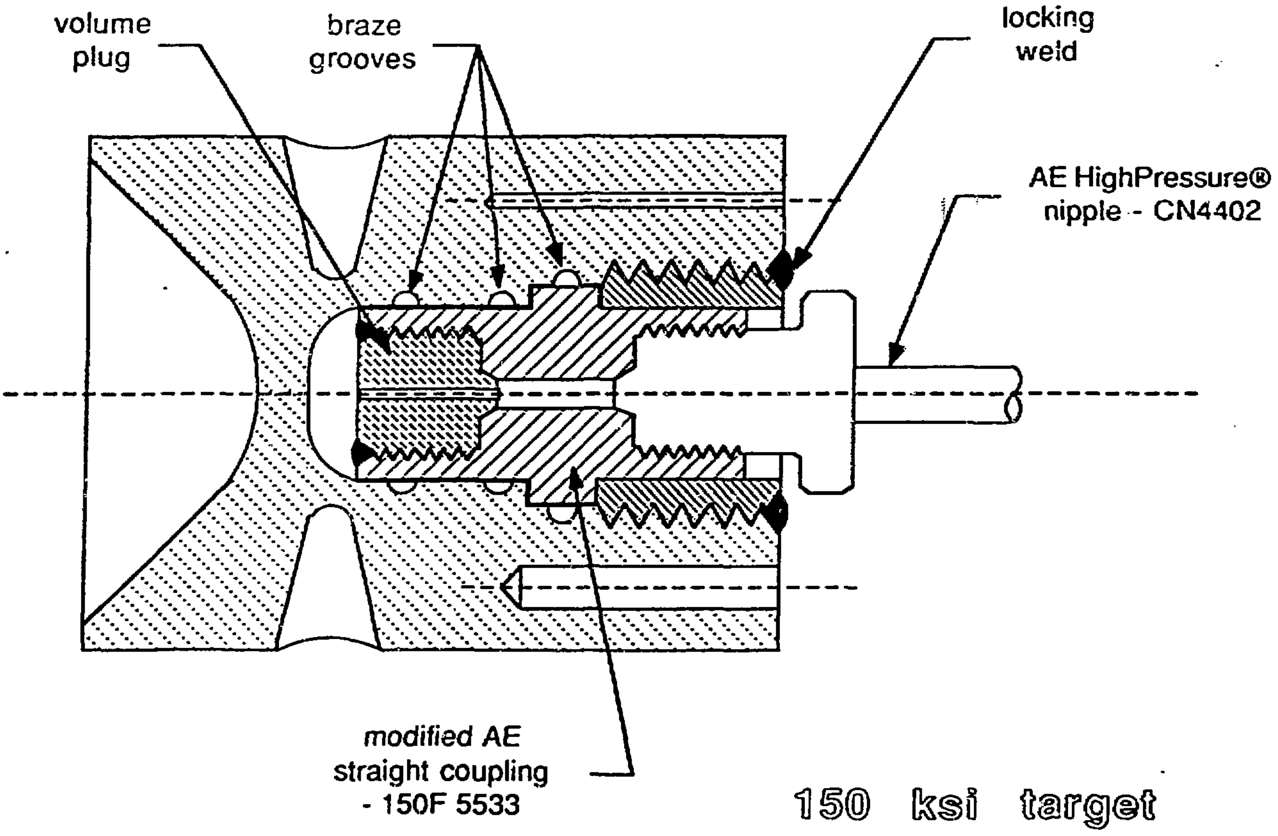

Figure 8. Target capsule design for a new LAMPF experiment, to achieve densities up to 2.3 LHD at cryogenic temperatures. Like its predecessors, this fifth-generation target flask is cylindrically symmetric.

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