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Comment on "Cluster-Impact Fusion"

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Beuhler, Friedlander, and Friedman (BFF) reported anomalously huge D-D fusion rates while bombarding deuterated targets with $(D_2O)_N^+$ clusters (N $\sim$ 25-1000) accelerated to $\approx$325 keV[1,2] [i.e. $\approx$0.3 keV lab energy for D in $(D_2O)_{100}^+$]. However, from our analysis of BFF's fusion product spectra, we conclude that their D lab energy was $\gtrsim$50 keV. Therefore, no gross anomalies exist. Also, from our analysis of the BFF beam-ranging experiments through 500 μg/cm^2 of Au,[2] we conclude that light-ion-beam contaminants (e.g. D^+ of order 100 keV) have not been ruled out.

BFF showed D-D proton peaks ($\approx$3 MeV) with widths (FWHM) of about 330 keV obtained with a surface barrier detector (SBD).[1,2] BFF[1] attribute this width to differential energy loss of 3-MeV protons passing through the 50-μg/cm^2 Al front layer of the SBD at various angles. However, we calculate this effect to be only $\sim$1 keV.[3] Broadening due to energy straggling is $\sim$5 keV.[4] About 20 keV is the electronic detector noise specified by the manufacturer; however, in our experience, $\sim$50 keV is easily obtained. Thus, a broadening of still $\approx$330 keV must be attributed to some other process, which we discuss henceforth.

In the BFF experiments, the cluster beam hits a deuterated target $\sim$1.5 cm from a 300-mm^2 SBD (Fig. 1). Thus the SBD subtends an angle (at its extreme) of about 60°. The D-D proton energy in the lab frame depends on the D-D center-of-mass velocity (a function of the initial D energy) and the angle (θ) between the proton and the initial deuteron directions (see Table 1 and Fig. 1). From Table 1 and the extent of the BFF proton peak, we conclude that the fusing deuterons have a lab energy of $\gtrsim$50 keV. (A smaller *effective* angle, which should apply to BFF, would imply a higher energy, thus the "$>$ " in $\gtrsim$50 keV.)

As a test for beam contaminants, BFF argue that ranging their cluster beam through 500 μg/cm^2 of Au will eliminate "cluster fusion" but not light-ion contaminant fusion (from D^+, D_2^+, D_3^+). This argument is not generally valid. A contaminant of, e.g., $\sim$100 keV D^+ will indeed penetrate 500 μg/cm^2 of Au; however, it loses 70 keV in ranging through,[3] and the fusion yield is reduced by $\sim$20 times. [The same reduction in fusion yield holds for D_2^+ (D_3^+) at ~200 keV (300 keV).] Indeed BFF did observe in such an experiment very roughly an order of magnitude decrease in the fusion rate (the experiment statistics are poor), but they interpret this as proof that light contaminants are not causing their observed rate.[2,5] We disagree. Furthermore, while BFF believe they have eliminated oxygenated light contaminants from the ion source up to the first stages of their accelerator,[5] we feel that contaminants formed by, for example, ionization in the accelerator tube subsequent to splash-back from the apertures have not been *convincingly* precluded.[6,7] Finally, we note that with a ~100 keV D^+ (~300 keV D_3^+) contaminant, for instance, only of order 1 D^+ (D_3^+) per 3000 (10000) clusters [$(D_2O)_{100}^+$ at 1 nA] is needed to produce the BFF fusion rate.

Therefore, from our analyses of the BFF data, from the negative theoretical results,[6,8] and from the negative cluster experiment with *post*-acceleration mass and energy analyses,[7] we conclude that a light-ion contaminant has not been ruled out. To do such will probably require *post*-acceleration mass and energy analyses.[7]

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Table 1: D-D proton energy (MeV) depends on the D-D c.m. velocity (a function of the D lab energy, E_D) and the lab angle, θ (Fig. 1). ΔE is the energy (MeV) extent of protons collected by an SBD at 90° when it subtends an angle of $\approx$60°, a value appropriate for the BFF experiments.

E_D(keV)	0°	60°	90°	120°	180°	ΔE
1	3.062	3.042	3.023	3.003	2.984	.039
10	3.151	3.087	3.025	2.964	2.904	.123
50	3.323	3.176	3.035	2.900	2.772	.276
100	3.464	3.249	3.048	2.858	2.681	.391

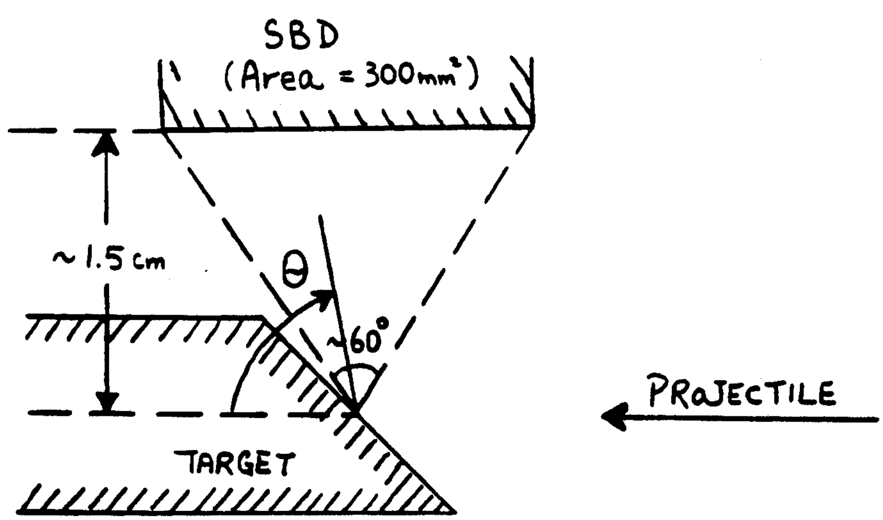

Figure 1: Geometry of BFF experiment.