Nuclear Structure for Nuclear Astrophysics

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All the heavy elements found in the solar system have been formed in stellar processes either by steady burning or in explosive scenarios. In Nova explosions e.g., after a white dwarf in a binary system has accreted hydrogen from its companion star until a thermonuclear runaway has been triggered with subsequent ejection of material, light elements are formed. Since the relevant nuclides lie close to the valley of stability, the quantities necessary to calculate the reaction rates as a function of temperature are accessible to high resolution experiments. The calculated element formation can then be compared with the results of infrared and radio observations.

We have used the MLL tandem accelerator together with the Q3D magnetic spectrograph to investigate levels close to the proton emission threshold in nuclei that are formed in the reaction pathway of Novae. Nuclear states in ^{19}Ne [1], ^{20}Na, ^{24}Al, ^{28}P, ^{32}Cl, ^{36}K [2], ^{31}S [3], and ^{34}Cl [4] have been excited with the (^{3}He,t) reaction, in ^{27}Si [5] with (^{3}He,α) and in ^{31}S [6] also with(d,t). In many cases targets were used where the target element of interest was implanted into carbon foils at the Univ. of Washington. Precise excitation energies and spin-parity assignments could be obtained even for not resolved states by measuring angular distributions.

As an example we show part of the spectrum at three lab angles for the ^{18}F(^{3}He,t)^{18}Ne reaction just above the proton threshold in ^{18}Ne at an excitation energy of 6.411 MeV. The energy resolution of 14 keV (FWHM) at the ^{3}He beam energy of 25 MeV allows for the first time to identify three states within 50 keV above the threshold. Their angular distribution can also be extracted and by comparison with a DWBA calculation Spin-parity assignments can be suggested. Previous assignments of two $3/2^+$ states in this triplet has to be rejected and thus the previous assumption that the interference between the $3/2^+$ states just above threshold and one a 665 keV above threshold has a large influence on the reaction rate for the ^{18}F(p,α)^{15}O reaction. The latter destruction reaction is important for the amount of ^{18}F left over after the Nova and in principle observable through it β^+ emission by the 511 keV γ-rays. Thus we have to conclude that the ^{18}F abundance is not determined by interference effects, but to a large extent by the width of the 6459 keV state.

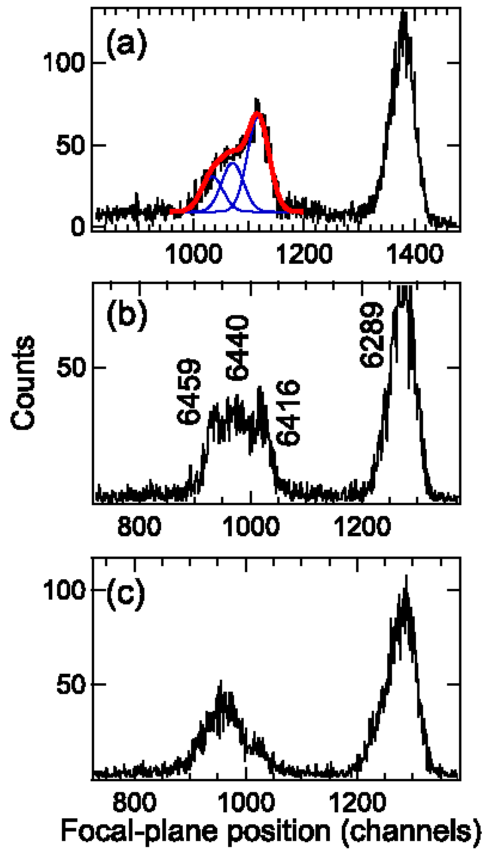

Figure 1: Partial raw focal-plane triton spectrum at 15° (a), 20° (b), and 30° (c). At 15°, the overall best fit (red) and three constituent Gaussian peaks (blue) are shown for the states within E_x = 6.4 – 6.5 MeV.

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