Calculation of background reactions for $^{59}Fe(d,p)^{60}Fe$

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Another 2019 TAMU Annual Report discusses the excitation energy resolution and reaction rate for the reaction of $^{59}Fe(d,p)^{60}Fe$ @ 7.5 MeV/u which is of astrophysical and geological interest as well as of nuclear interest. This report discusses the main anticipated sources of background in this reaction, and proposes a means to deal with them.

The radioactive ion beam developed with MARS at TAMU contains some heavy and light species. Of the heavy species, 79% is the desired ^{59}Fe, 13% is ^{57}Co, and 7% is ^{59}Co. If the iron can be distinguished from cobalt, the lighter species will be trivial.

The target is to be CD2 with purity greater than 95%. Fusion evaporation reactions on carbon, deuterium, and protons must be considered.

PACE4 (packaged with LISE++) calculations indicate that for fusion of ^{59}Fe on ^{1}H and ^{2}H produce negligible charged products backward of 120 degrees. The excitation energy is low enough that particles are rarely ejected with sufficient velocity to overcome the boost of the compound nucleus. The yield of such rare particles is expected to be a factor of 70 below the yield of the desired protons from (*d,p*).

Fusion of ^{59}Fe on ^{12}C creates compound nuclei with high enough excitation energy that charged particles can be evaporated with enough velocity to overcome the velocity boost of the compound nucleus and strike the silicon detector backward of the target. These cannot be discriminated from protons from the (*d,p*) reaction by only the energy and angle of the light charged particle. The velocity of the residue, however, does provide a means to discriminate. From momentum conservation, the compound nucleus in ^{59}Fe + ^{12}C fusion is significantly slower than the (*d,p*) residues. Fig. 1 shows the separation. The angle of the proton in the lab frame is plotted against the time of flight of the heavy residue across a 1 m flight path. The color shows the yield of protons produced in carbon fusion reactions. The red cross-hatched region shows the kinematically allowed range for $^{59}Fe(d,p)^{60}Fe$ reactions. These regions are well separated requiring no better than 1 ns time resolution.

The cobalt beam contaminants can undergo (*d,p*) reactions that are kinematically indistinguishable from the iron. Energy loss measurement of the beam particles event by event appears to be a possible way forward. Energy loss was calculated for an 20 mm thick ionization chamber with 30 Torr of isobutate and a total of 1.5 um mylar windows. Iron @ 7.5 MeV/u loses 5.42 MeV total in the mylar and 6.49 MeV in the gas. Cobalt @ 7.5 MeV/u loses 5.75 MeV total in the mylar and 6.78 MeV in the gas. The difference in energy loss in the gas of 390 keV is a difference of 6.1%. Thus an energy loss detector that is radiation hard to the 1E5 particle/sec level with an energy resolution sufficient to resolve peaks separated by 6.1% will allow event-by-event identification of beam contaminants.

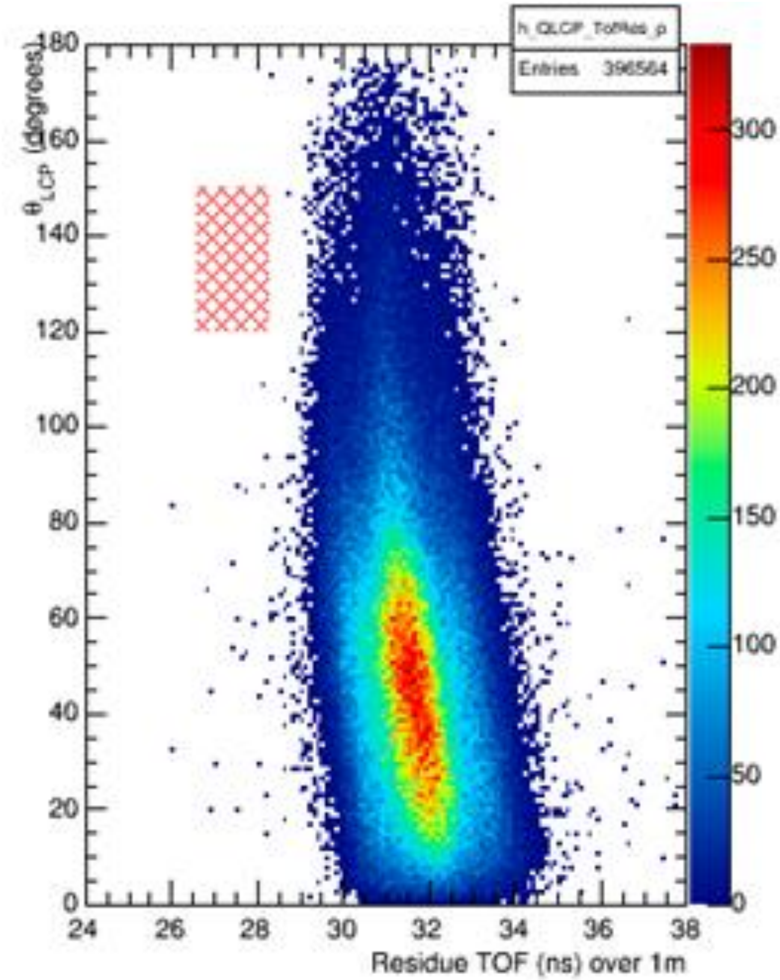

FIG. 1. GEMINI calculation for ^{59}Fe + ^{12}C fusion evaporation at 7.5 MeV/u. The angle of evaporated protons is shown as a function of the flight time of the heavy residue on a 1 m flight path. The red cross-hatched region indicates the region of interest for proton angle and residue time of flight for $^{59}Fe(d,p)^{60}Fe$ reactions.