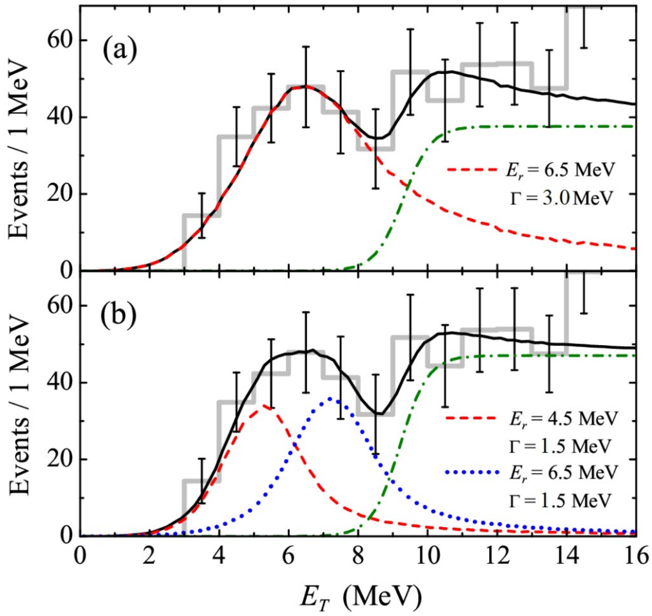
Add-on material on ^{6}H populated in ^{8}He(d,^{4}He) reaction

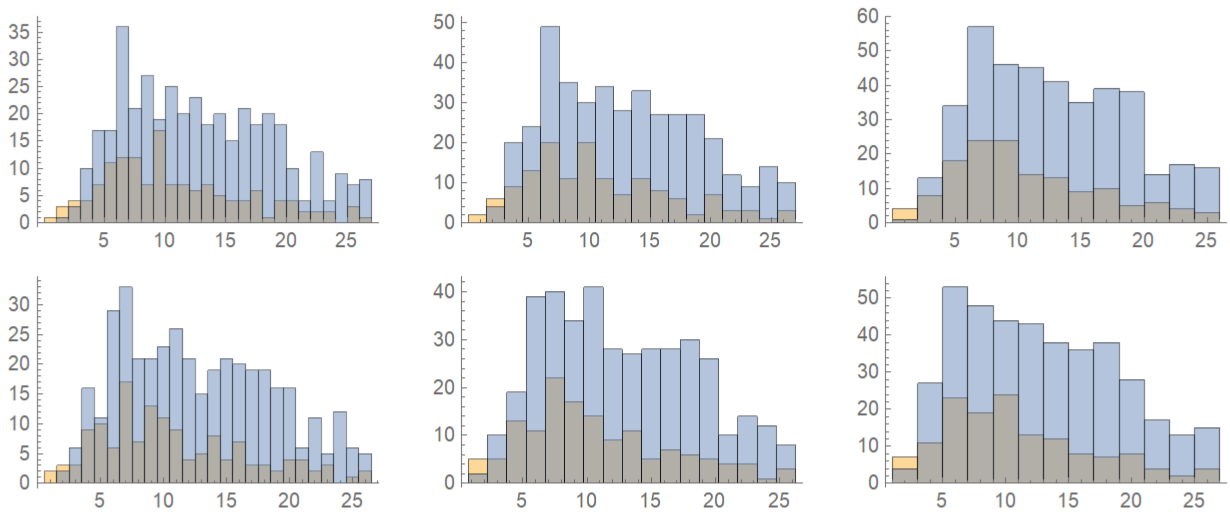
Some additional data cuts

Some preliminary version of the data analysis (now Fig. 6). 4He-3H coincidences, empty target background subtracted. No center-of-mass angle cut-off, no efficiency correction.

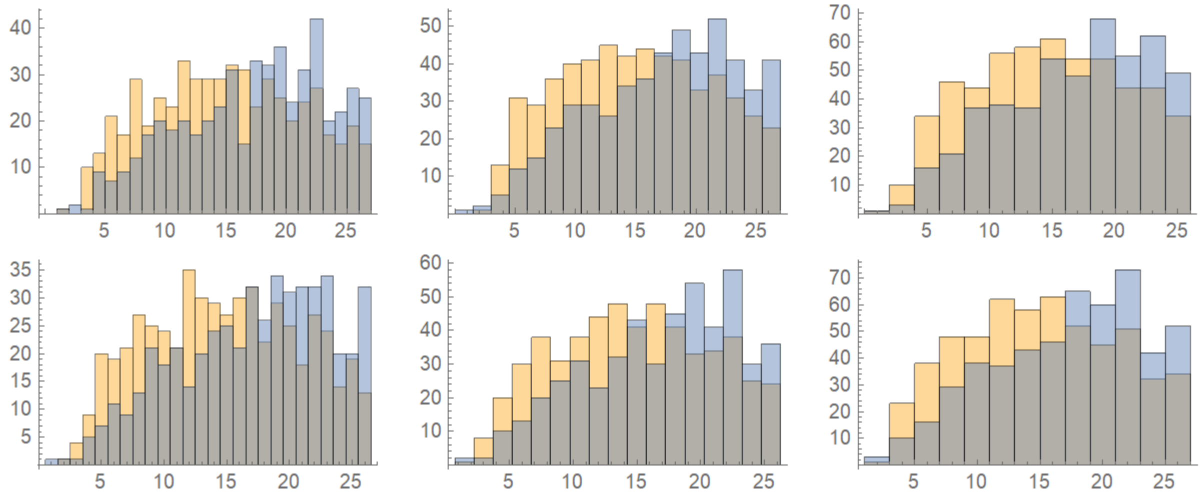


Six panels correspond to bin sizes {1,1.5,2} MeV in columns and in two rows the bin offsets are 0% and 50% of the bin size.

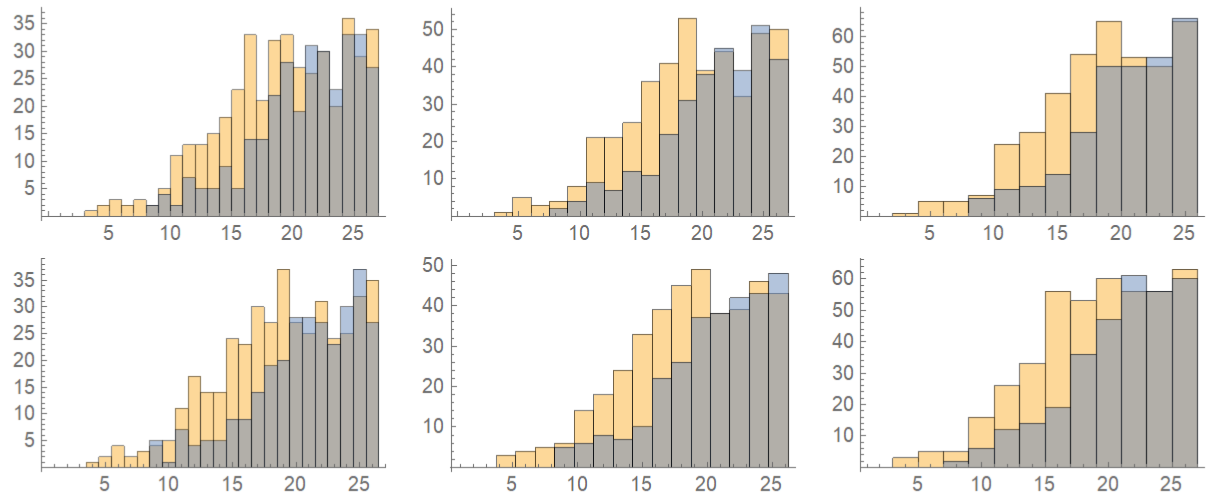
$\theta_{c.m.}$ = 0-8° (yellow) and $\theta_{c.m.}$ = 8-12° (blue). The color looks gray when these colors overlap.



$\theta_{c.m.}$ = 12-16° (yellow) and $\theta_{c.m.}$ = 16-20° (blue)



$\theta_{c.m.}$ = 20-24° (yellow) and $\theta_{c.m.}$ = 24-28° (blue)

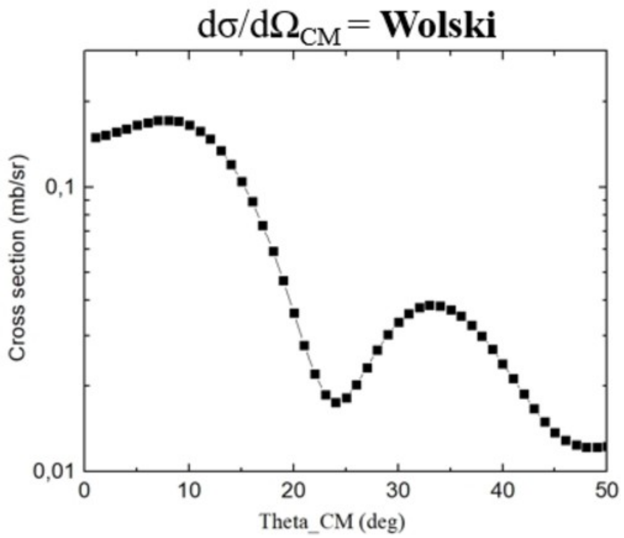


Local conclusions:

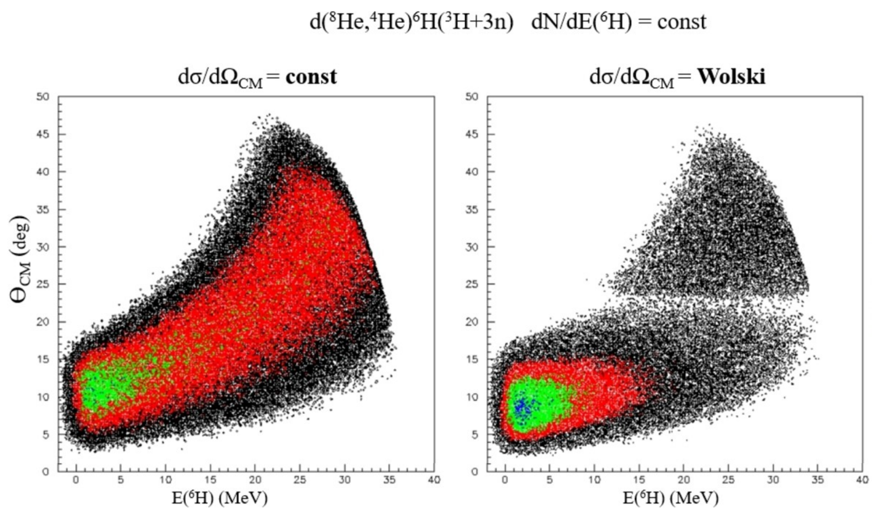
For cmall c.m. angles $\theta_{c.m.}$ = 0-8° and $\theta_{c.m.}$ = 8-12° the 6.8 MeV peak is always seen in all representations of the data. The situation is less certain at $\theta_{c.m.}$ = 12-16°. For the $\theta_{c.m.}$ = 16-20° range the spectrum is smooth within the statistical fluctuations. For the $\theta_{c.m.}$ = 20-24° some “remnants” of the 6.8 MeV peak can be spotted, and for the $\theta_{c.m.}$ = 24-28° it is clear that the efficiency has “killed” everything around 6.8 MeV.

6H c.m. angular distribution and MC simulations of efficiency

The cross section of the $^{8}He(d,^{4}He)^{6}H$ reaction for population of the expected low-lying resonant states of 6H was calculated by R Wolski using the FRESCO code for $\Delta l = 1$ momentum transfer. The obtained cross section feature peak at about $\theta_{c.m.} = 8^{o}$ rapid fall after $\theta_{c.m.} = 14\text{-}16^{o}$ and diffraction minimum around $\theta_{c.m.} = 24^{o}$. The obtained cross section fall after 14-16° is consistent with absence of the 6.8 MeV peak in the experimental MM spectrum for $\theta_{c.m.} > 16^{o}$.

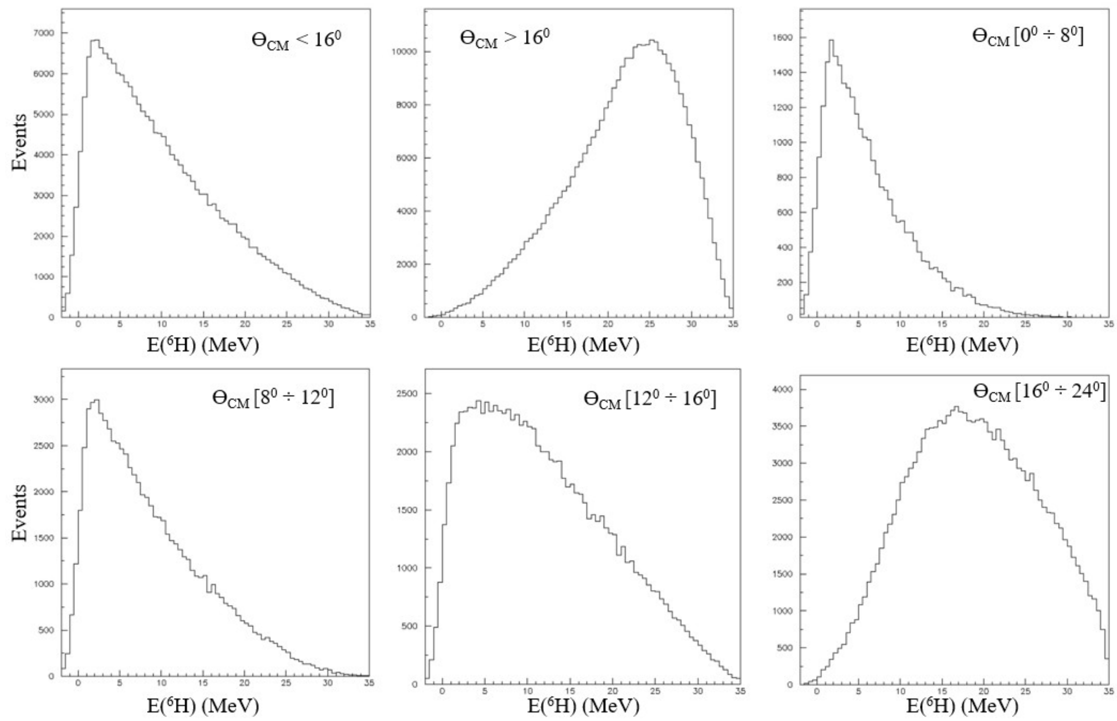


For MC simulations of the setup efficiency two assumptions about c.m. angular distribution of the $^{8}He(d,^{4}He)^{6}H$ reaction were used: (i) isotropic distribution and (ii) FRESCO $\Delta l = 1$ distribution.

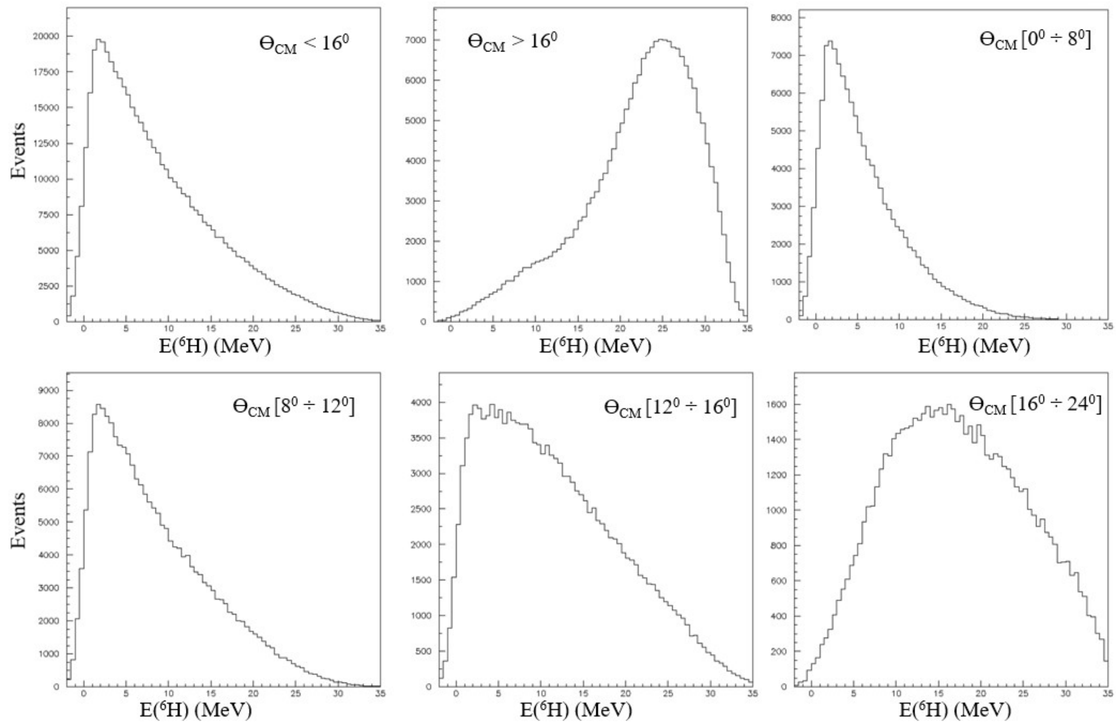


The efficiencies obtained in these assumptions for different c.m. angular ranges are reasonably close.

$d(^8He,^4He)^6H(^3H+3n)$ $d\sigma/d\Omega_{CM} = const$; $dN/dE(^6H) = const$



$d(^8He,^4He)^6H(^3H+3n)$ $d\sigma/d\Omega_{CM}$ = Wolski; $dN/dE(^6H) = const$



Local conclusions:

(i) The registration efficiency of our setup for $\theta_{c.m.} < 14^o$ is optimal for registration of state with E_T ~ 2.6-2.9 MeV, however, nothing is observed in this energy range.

(ii) For $\theta_{c.m.} < 16^o$ the efficiency is always monotonous and has quite weak energy dependence in the energy range E_T ~ 3-8 MeV, where the resonant state(s) of 6H are observed.

(iii) For $\theta_{c.m.} > 16^o$ the efficiency in the energy range E_T ~ 3-8 MeV begin to suppress the 6.8 MeV state population, and for $\theta_{c.m.} > 22^o$ registration of this state becomes impossible.

Possible sources of physical background for the $^{8}He(d,^{4}He)\ ^{6}H$ reaction

The channel identification of our data (4He+3H and 4He+3H+n coincidence events) actually corresponds to 4 reaction channels

(i) 6H+4He
(ii) 5H+5He
(iii) 4H+6He*(4He+2n)
(iv) 3H+7He*(4He+3n)

All these reaction channels correspond to the same (4He+3H+3n) continuous spectrum and are distinguished by how the 3 neutrons are distributed in the momentum space.
Each of these reactions has 2 branches with fast (beam-like) 3H or fast 4He

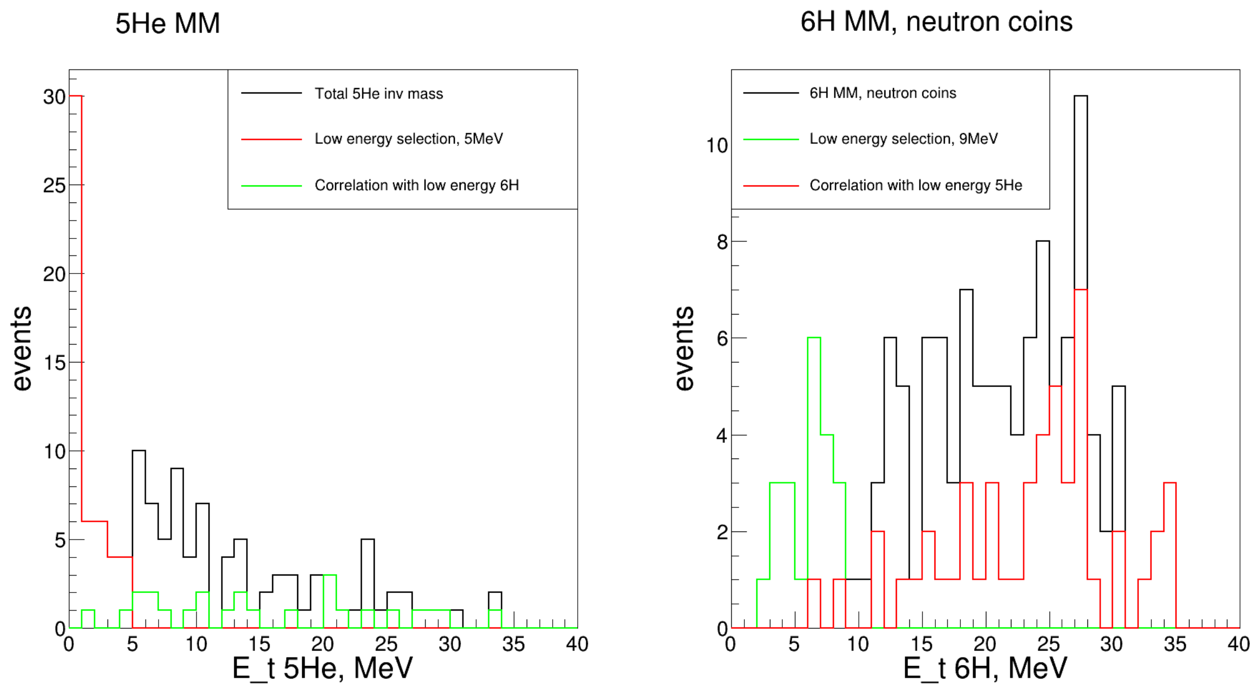
fast 3H	fast 4He
1) d transfer to the target	5) 4n transfer to the target
2) d+n transfer to the target	6) 3n transfer to the target
3) d+2n transfer to the target	7) 2n transfer to the target
4) d+3n transfer to the target	8) n transfer to the target

The Q values for all these reactions are not significantly different (just few MeV). It is reasonable to expect that only the reactions number 1, 2, 7, 8; the other look too complicated. Also our setup (forward 3H telescope, sideways 3He telescopes) favors the reaction channel with fast 3H.

A priori, we can not exclude "contamination" of the 6H spectrum by the events which are actually connected with resonances in the channels (ii)-(iv). Possible importance of such "physical backgrounds" in our data can be clarified by studies of channels (ii)-(iii)using reconstruction allowed by the 4He+3H+n coincidence events.

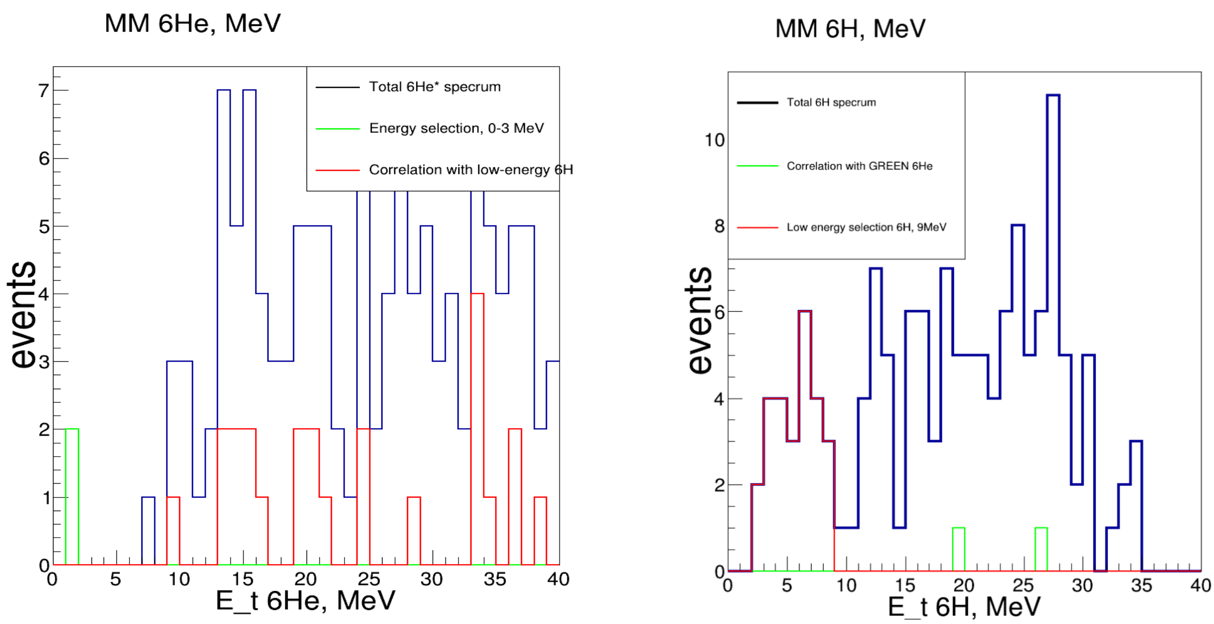
(ii) 5H+5He channel

The 5He g.s. (strong feed to the first 1 MeV bin) is well seen in the data. The low-lying 5He events (E_T < 5 MeV, red histogram left panel) are located in the spectrum of 6H mainly around E_T = 25 MeV; only two events can be found in the range E_T < 9 MeV presumably associated with the resonant states of 6H. Vice versa, the events corresponding to the assumed resonant states of 6H with E_T < 9 (green histogram in right panel) are evenly distributed in the spectrum of 5He from 5 to 35 MeV.



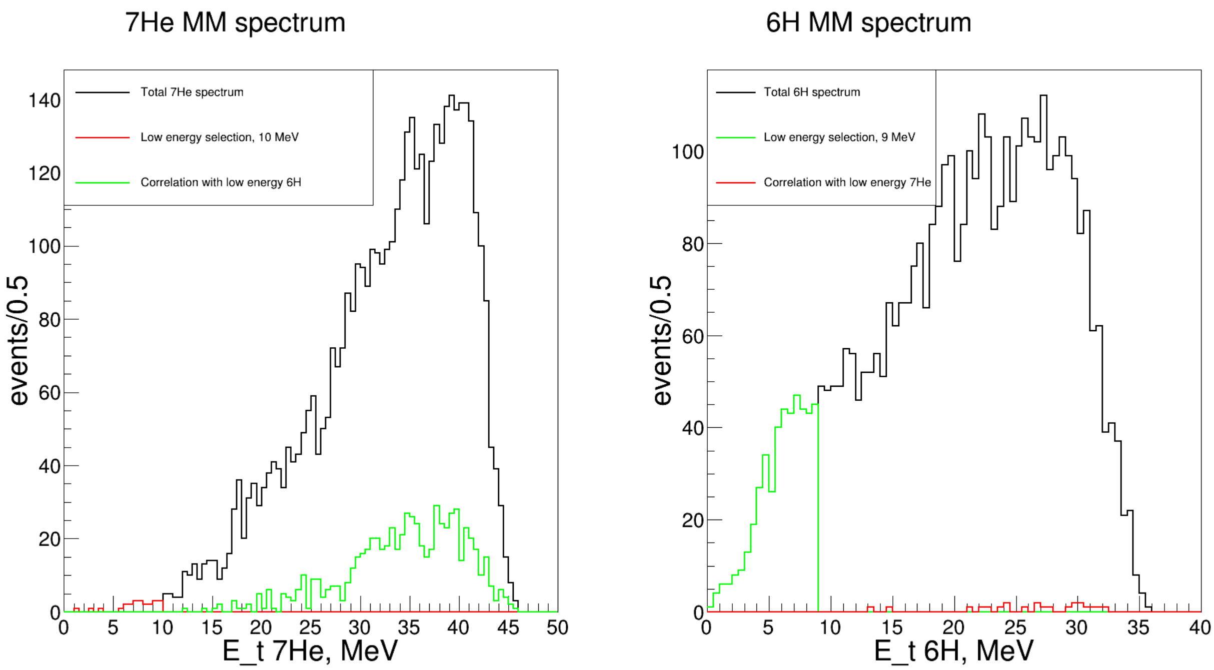
(iii) 4H+6He* channel

The low-energy spectrum of 6He* (here in the left panel it is shown from the 4He+n+n threshold) is poorly populated in our reaction conditions. Just two events can be found at about 1 MeV of excitation, which could be associated with the 2+ state of 6He. These events are associated with high-energy (20-25 MeV) part of the 6H MM spectrum. If we have a look in the opposite direction, then the events from the low-energy $E_T < 9$ MeV part of the 6H spectrum (red events in the right panel) are reasonably concentrated in the ~ 15 MeV region of the 6He*. There are well-known 6He states in this region, however, their nature, which in known to be of 3H+3H cluster character, seem to be not very relevant to our channels of interest.



(iv) 3H+7He channel

The 7He*=4He+3n MM spectrum can be reconstructed using the data on 3H identification. Several events can be found in the excitation spectrum of 7He* from 5 to 9 MeV which could be possibly associated with the poorly known ~5.8 MeV state of 7He. The 7He events associated with this energy range (left panel, red histogram) correspond mainly to excitations from 20 to 35 MeV in 6H (right panel). The 6H events with E_T < 9 MeV – the energy range of the expected resonant states of 6H – correspond to excitation energies from 25 to 45 MeV in 7He.



Local conclusions:

We have considered ALL the reaction channels which may be an alternative to population of 6H resonant states in our reaction. These reaction channel are all defined by the 4He+3H or 4He+3H+n coincidence conditions. Population of the low energy states in 6He* and 7He* [reaction channels (iii) and (iv)] is very small, which is evidently a natural result of very complicated mechanism of these reactions [d+2n and d+3n transfer to the target]. In contrast, the population of the 5H+5He channel is very intense (low-energy spectrum of 5He with E_T< 5 MeV is ~2.5 times more populated than the low-energy spectrum of 6H with E_T< 9 MeV). Fortunately, the events which are associated with this channel do not contaminate the low-energy part of the 6H spectrum: these events considerably contribute to the 6H MM spectrum only for E_T>10 - 13 MeV. This is a good additional argument, that interpretation of the 6H spectrum for E_T< 10 MeV is safe, while for E_T> 10 MeV a lot of caution is needed.