STUDIES OF NUCLEAR-REACTIONS-IN-SOLID IN TITANIUM-DEUTERIDE UNDER ION BEAM IMPLANTATION

-Experiments with deuteron beam implantation-

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Introduction-1

Up to now, the charged-particle spectrum, figure 1, which suggest multi-body fusion have been observed, by implantation of deuteron beam to titanium deuteride (TiDx). We considered that the helium-3 and triton which had kinetic energy 4.75 MeV was emitted by 3D multi-body fusion.

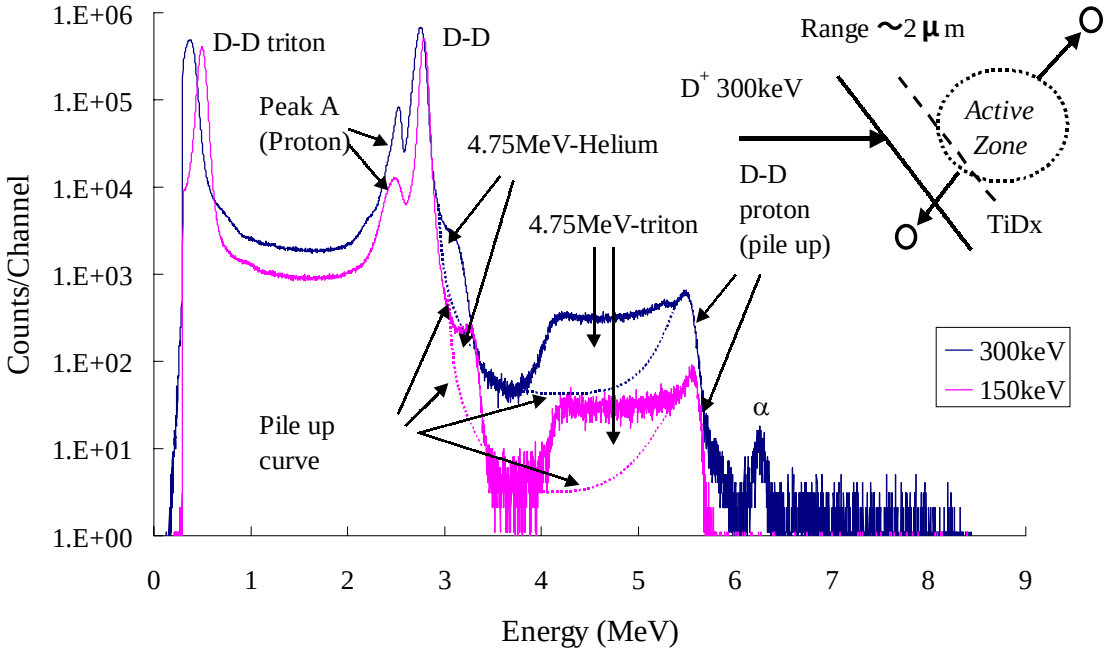


Fig.1 Charged-particles spectra emitted from TiDx sample implanted with 300keV-deuteron beam

Introduction-2

Multi-body fusion branch

・3D

$d + d + d \rightarrow {}^{6}Li^{*}$
- $\rightarrow t(4.75MeV) + {}^{3}He(4.75MeV)$ ・・・・・・・・・・・・(1)
- $\rightarrow d(15.9MeV) + {}^{4}He(7.93MeV)$ ・・・・・・・・・・・・(2)
- $\rightarrow n + p + {}^{4}He + 20.1MeV$ ・・・・・・・・・・・・・(3)

・4D

$d + d + d + d \rightarrow {}^{8}Be^{*}$
- $\rightarrow {}^{4}He(12.8MeV) + {}^{4}He(12.8MeV) + \gamma\ (22.2MeV)$ ・・(4)
- $\rightarrow {}^{4}He(9.95MeV) + {}^{4}He(9.95MeV) + \gamma\ (27.8MeV)$ ・・・・・・(5)
- $\rightarrow {}^{4}He(5.75MeV) + {}^{4}He(5.75MeV) + \gamma\ (36.3MeV)$ ・・・・・・(6)
- $\rightarrow {}^{4}He(0.046MeV) + {}^{4}He(0.046MeV) + \gamma\ (47.6MeV)$ ・・・・・(7)

Introduction-3

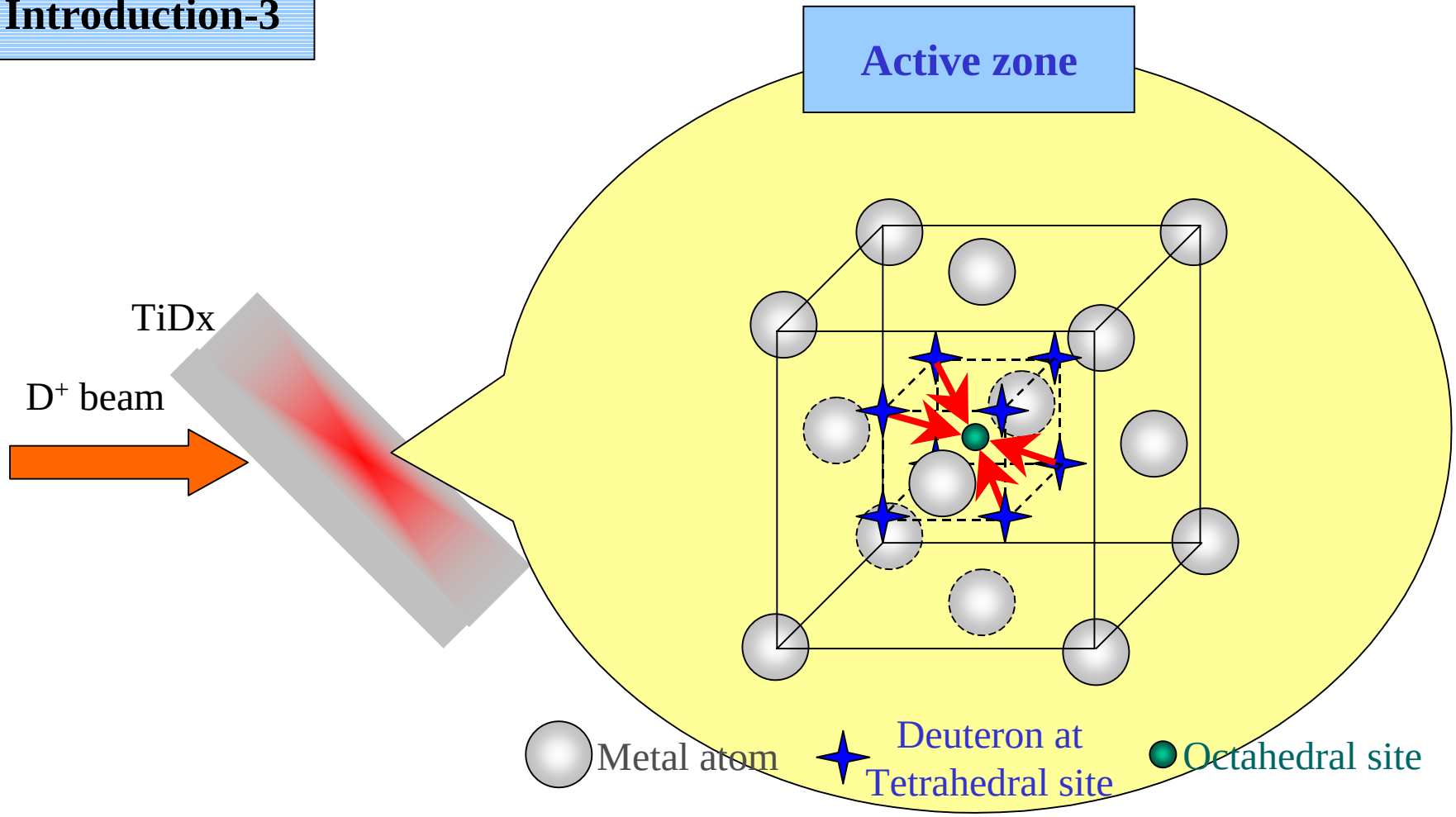


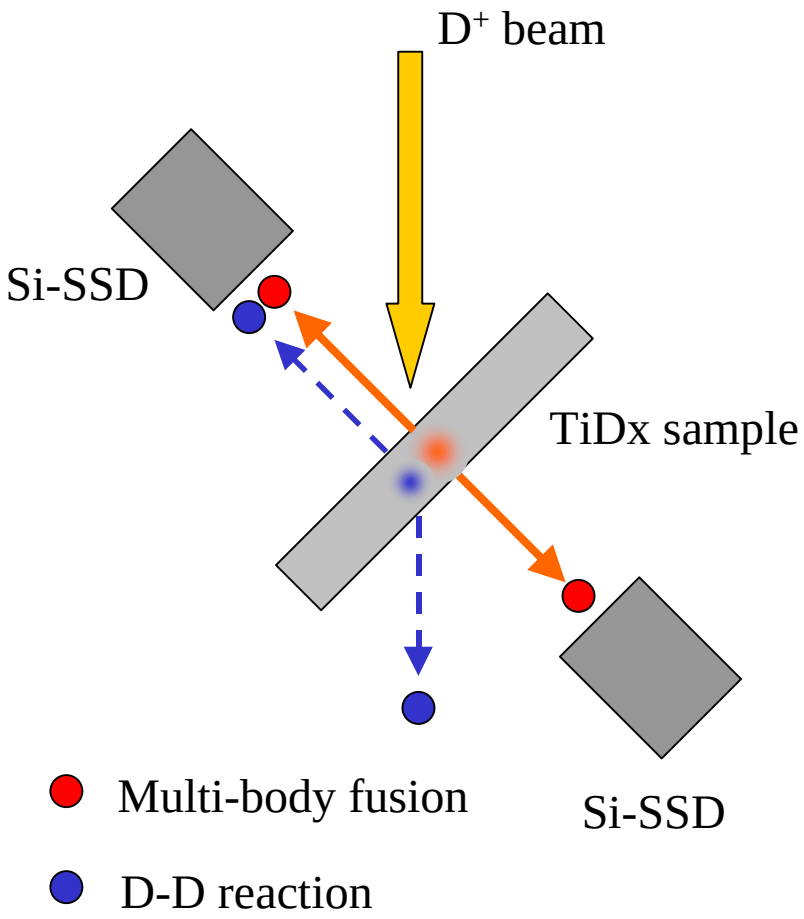
Fig.2 : This figure is the image of multi-body fusion. It was reported that the multi-body fusion was enhanced by transitional condition which was induced beyond the range of incident beam

Experimental purpose

D-D reaction prevent our detailed observing the spectrum which suggests the multi-body fusion.

Multi-body fusion occurs beyond the range of incident beam. So, the kinetic factor is equal to zero, and the reaction emit charged-particle at 180 degree symmetrically.

While, the kinetic factor of D-D reaction is not equal to zero. So, the reaction do not emit charged-particle at 180 degree symmetrically.



180 degree symmetric coincidence experiment can observe the detailed spectrum which suggests multi-body fusion.

Experimental System

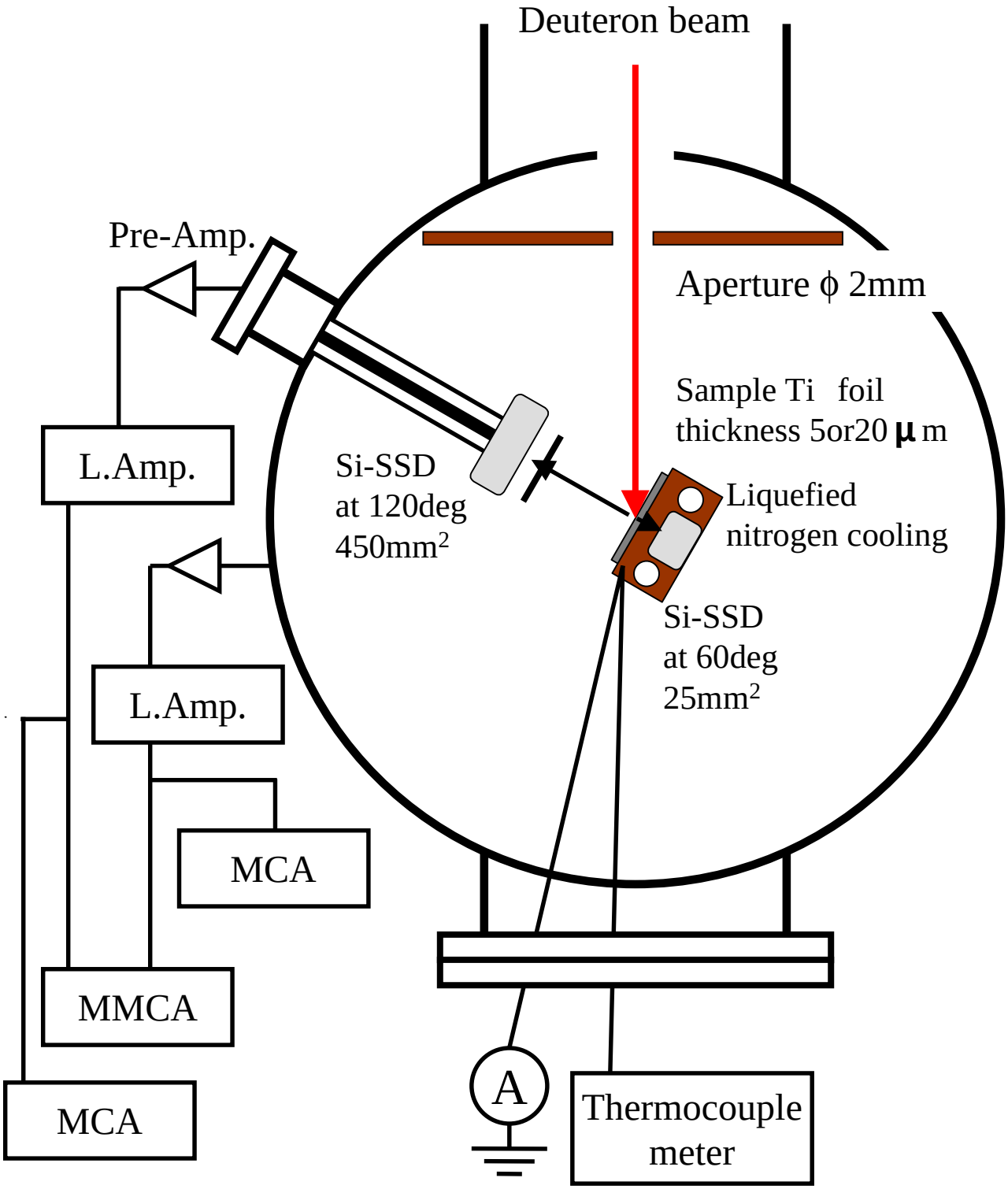


Fig.3:Schematic drawing of the experimental apparatus

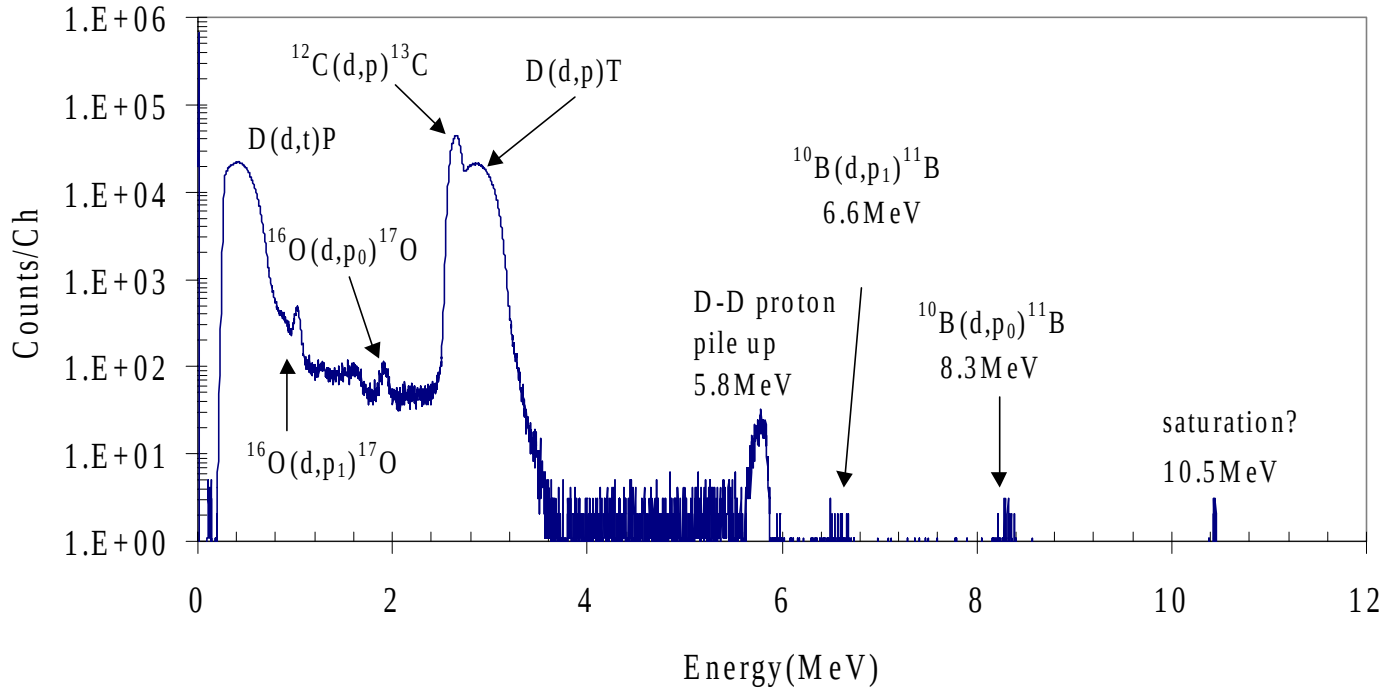


Fig.4:Charged-particle spectrum observed by 120 deg. Si-SSD emitted from Ti sample (thickness 5 μm) implanted with 300keV deuteron beam (Target current 1 μA)

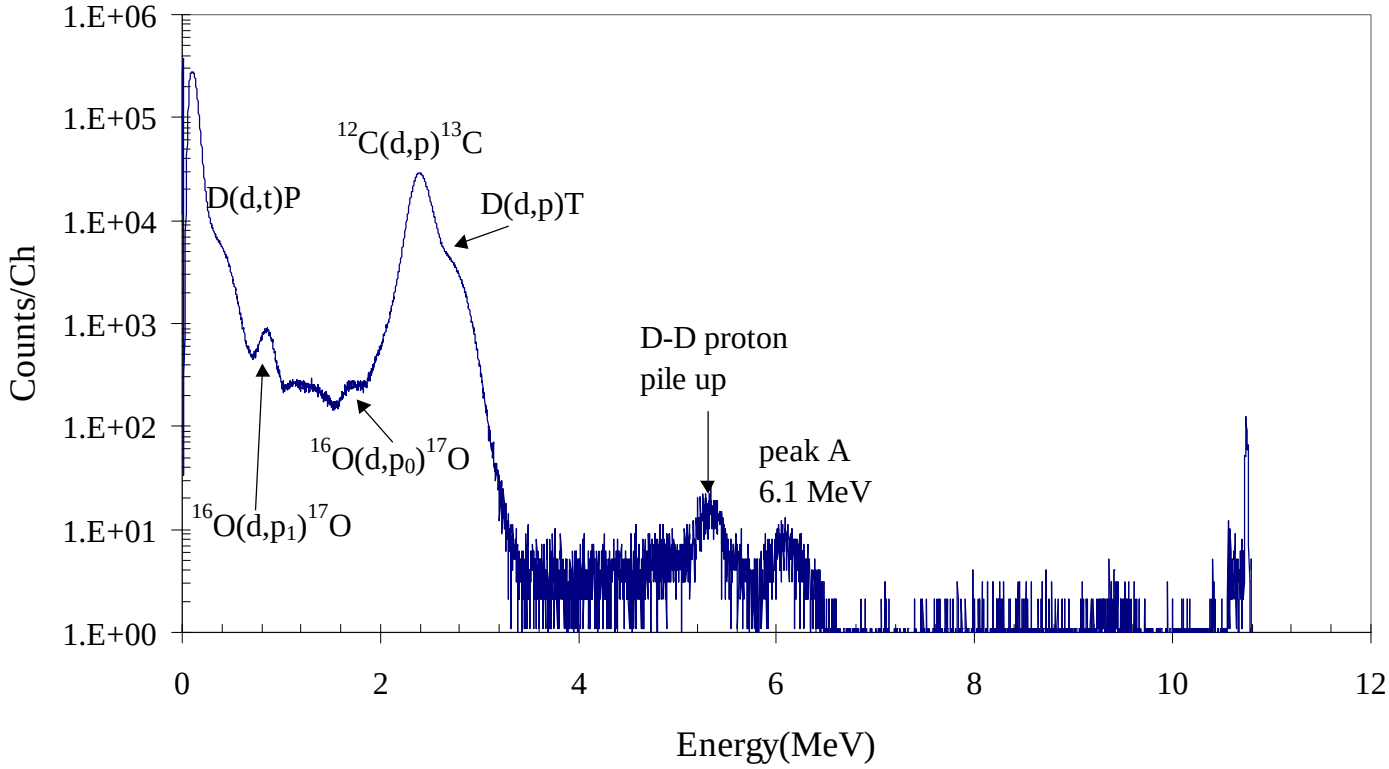


Fig.5:Charged-particle spectrum observed by 120 deg. Si-SSD emitted from Ti sample (thickness 20 μm) implanted with 300keV deuteron beam (Target current 10 μA)

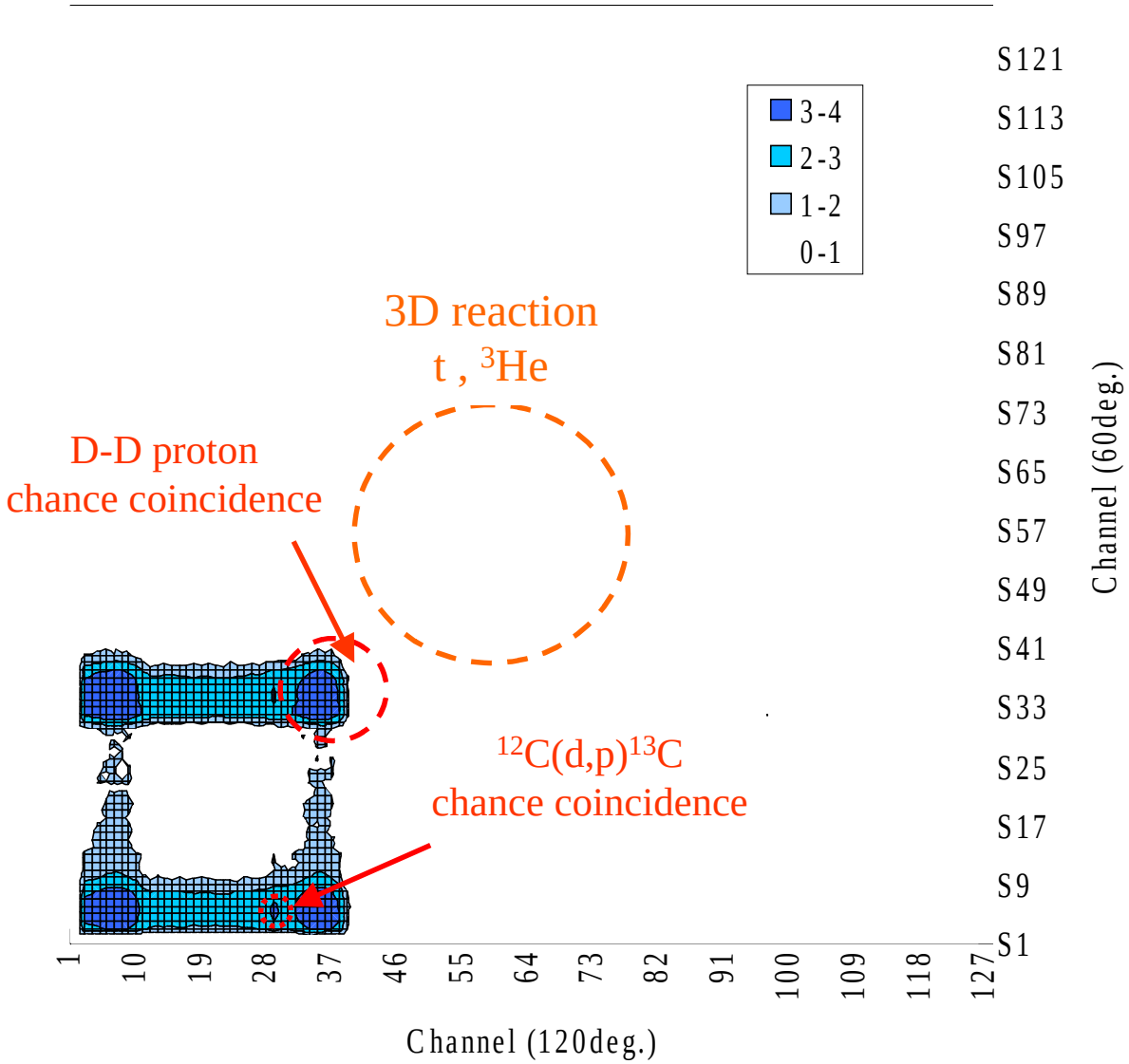


Fig.6:This figure is the coincidence spectrum recorded MMCA.X-axis is the charged-particle spectrum observed 120deg. Si-SSD.Y-axis is that observed 60deg. Si-SSD.

It was not a sufficient deuteron loading

The impurity reaction to D-D proton is much in comparison with the spectrum which is observed up to now.

Why?

To rise the deuteron loading ratio, we did cooling target. Therefore it produced wide temperature gradient at cooling side and irradiation side, and proceeded the damage of a sample.

or

For the reason which is short of thickness of the sample, it did not create coherent in metal lattice.

We considered that the reason that the spectrum which suggested multi-body fusion was not observed was short of thickness of sample. So, we paid attention to another branch.

$3D \rightarrow {}^{6}Li^{*}$

$\hookrightarrow d(15.9MeV) + {}^{4}He(7.9MeV)$

As for this coincidence experiment, a comparatively thick sample(500 μm) can be used.

At 60 degree Si-SSD:15.9MeV→5MeV

Experimental System

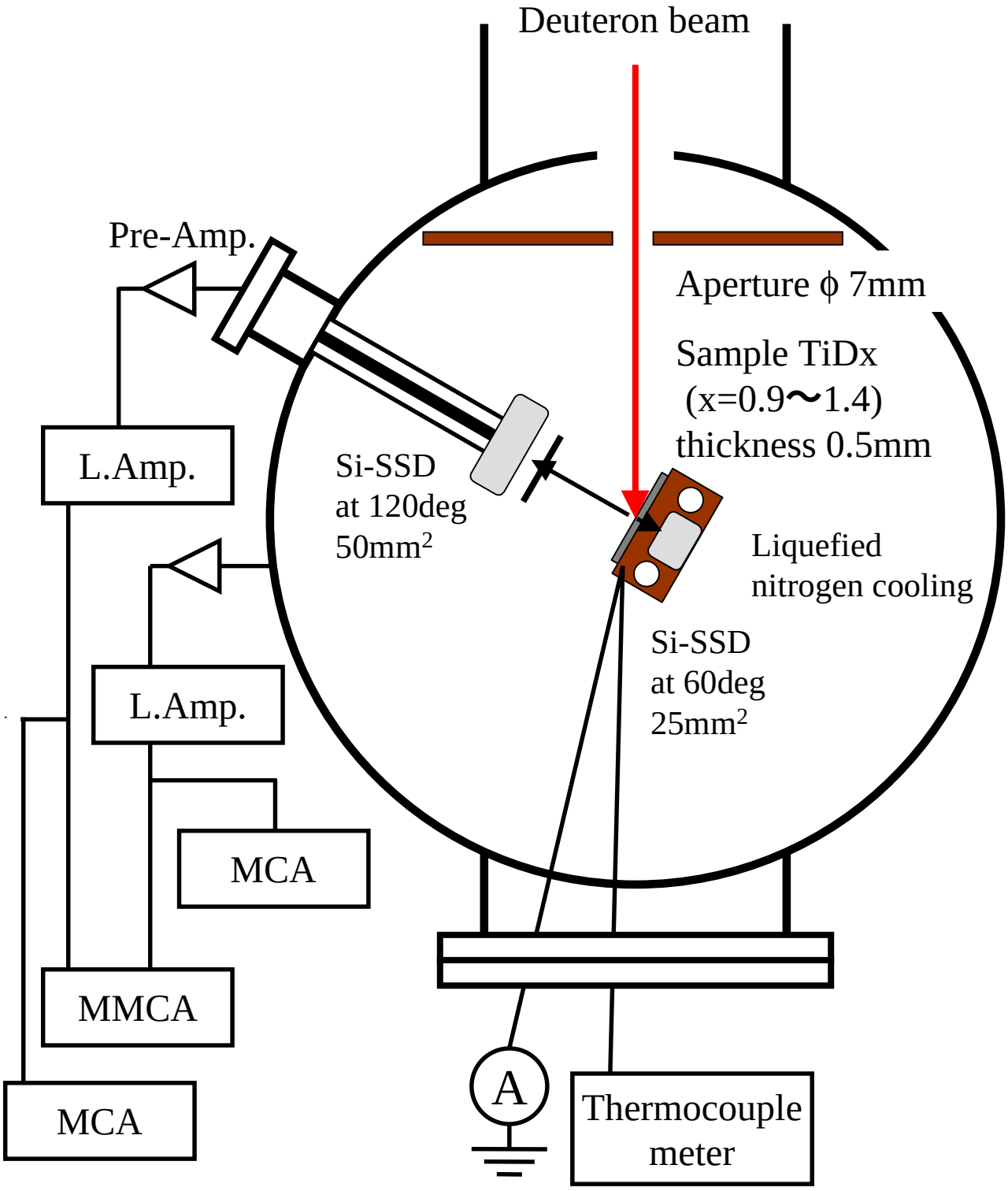


Fig.7:Schematic drawing of the experimental apparatus

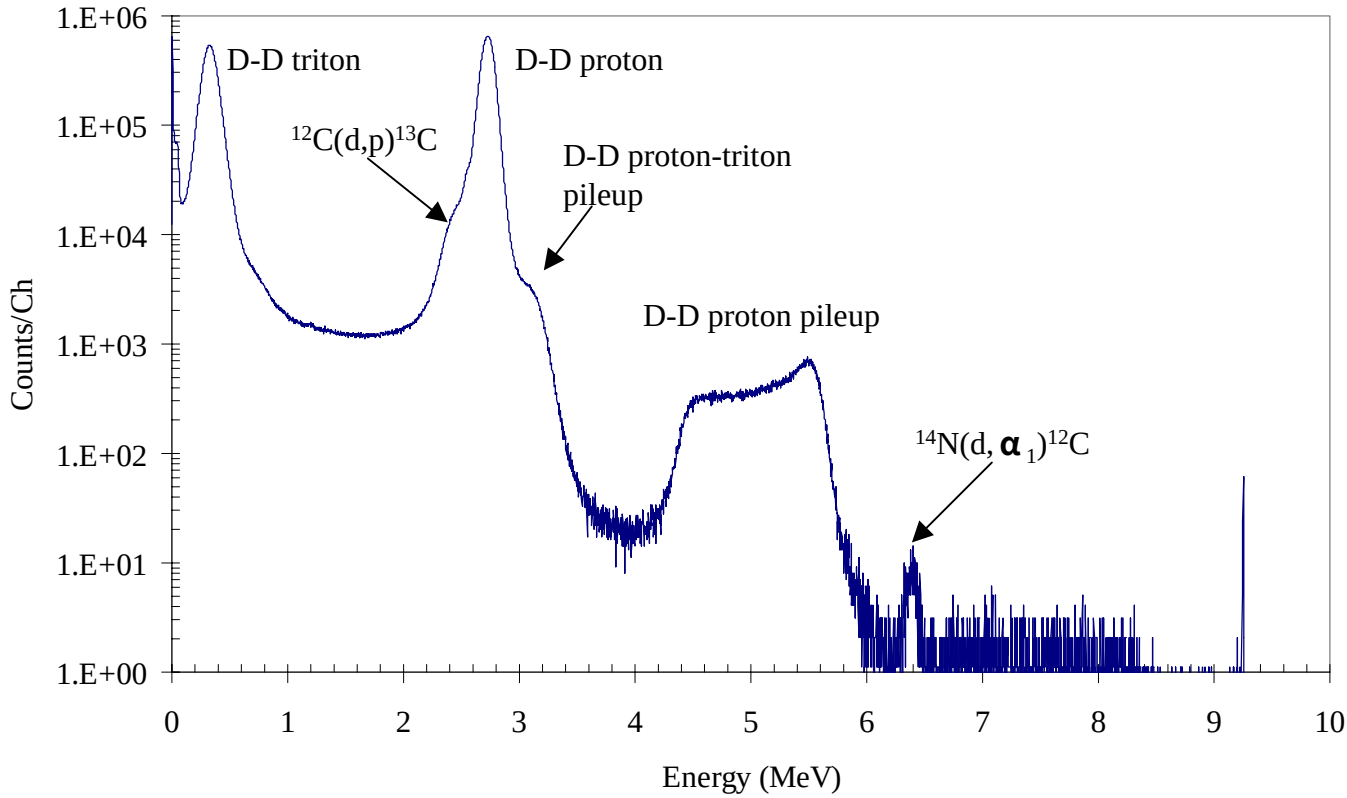


Fig.8:Charged-particle spectrum observed by 120 deg. Si-SSD emitted from TiDx sample (500 μm thickness) implanted with 300keV deuteron beam

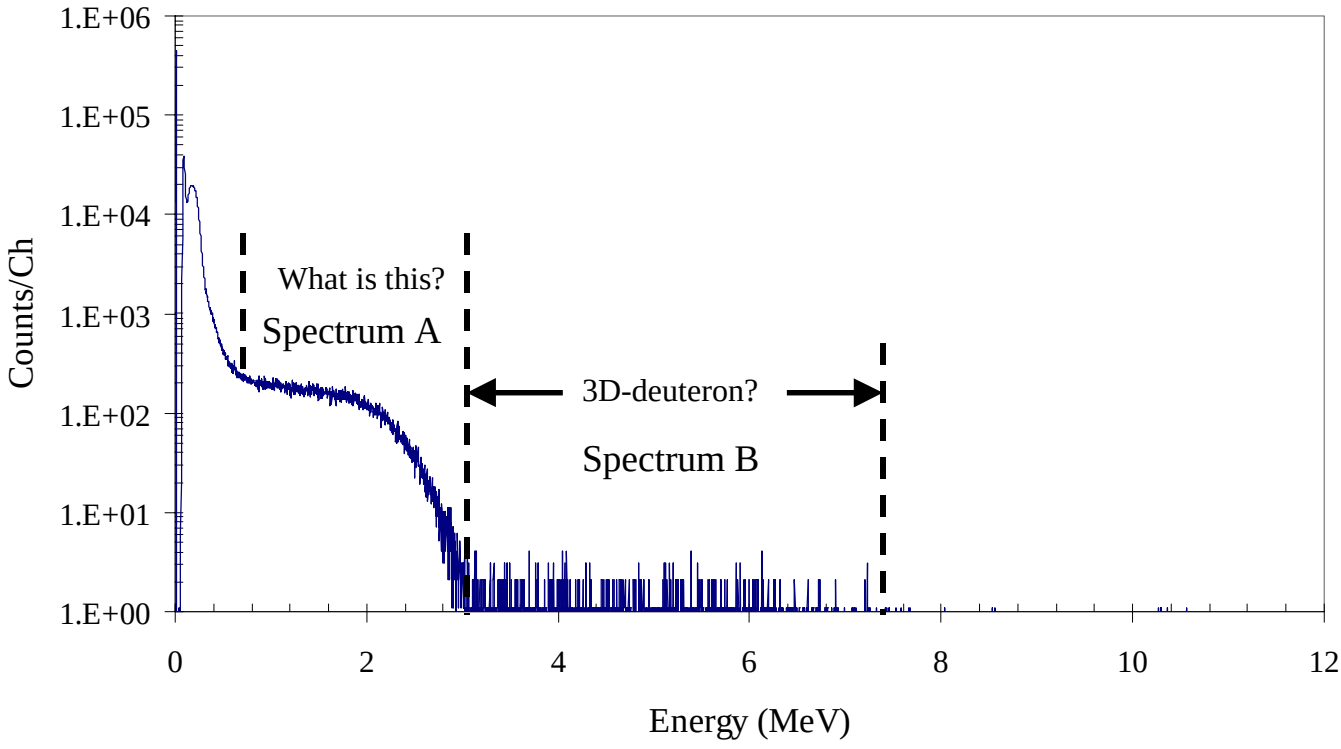


Fig.9:Charged-particle spectrum observed by 60deg. Si-SSD emitted from TiDx sample (500 μm thickness) implanted with 300keV deuteron beam

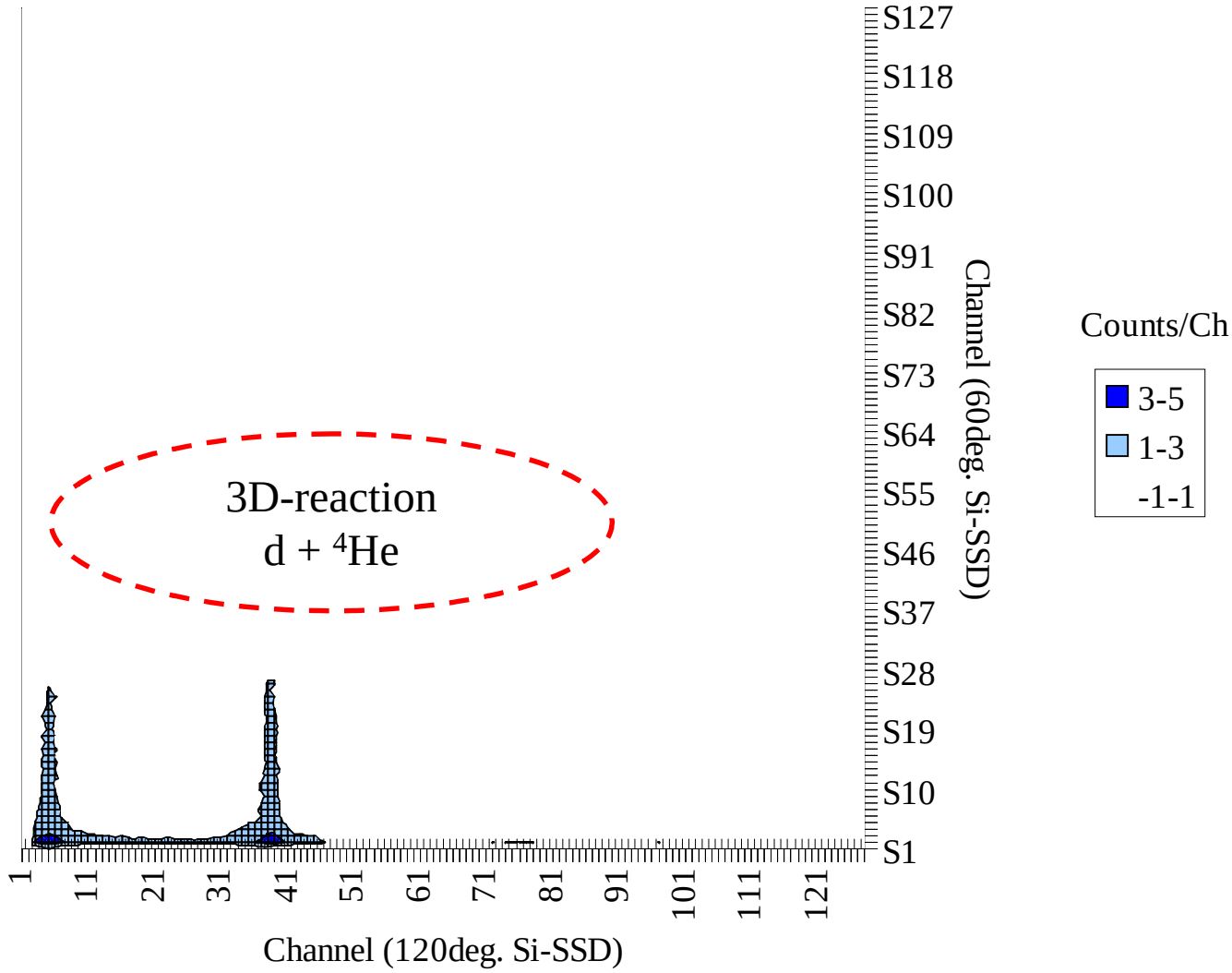


Fig.10:This figure is the coincidence spectrum recorded MMCA.X-axis is the charged-particle spectrum observed 120deg. Si-SSD.Y-axis is that observed 60deg. Si-SSD.

Spectrum A

We tried to identify spectrum A. The metal foil which was Ti foil (50 μm thickness) set front of 60deg. Si-SSD.If spectrum A is proton, spectrum A is had kinetic energy under 1MeV.

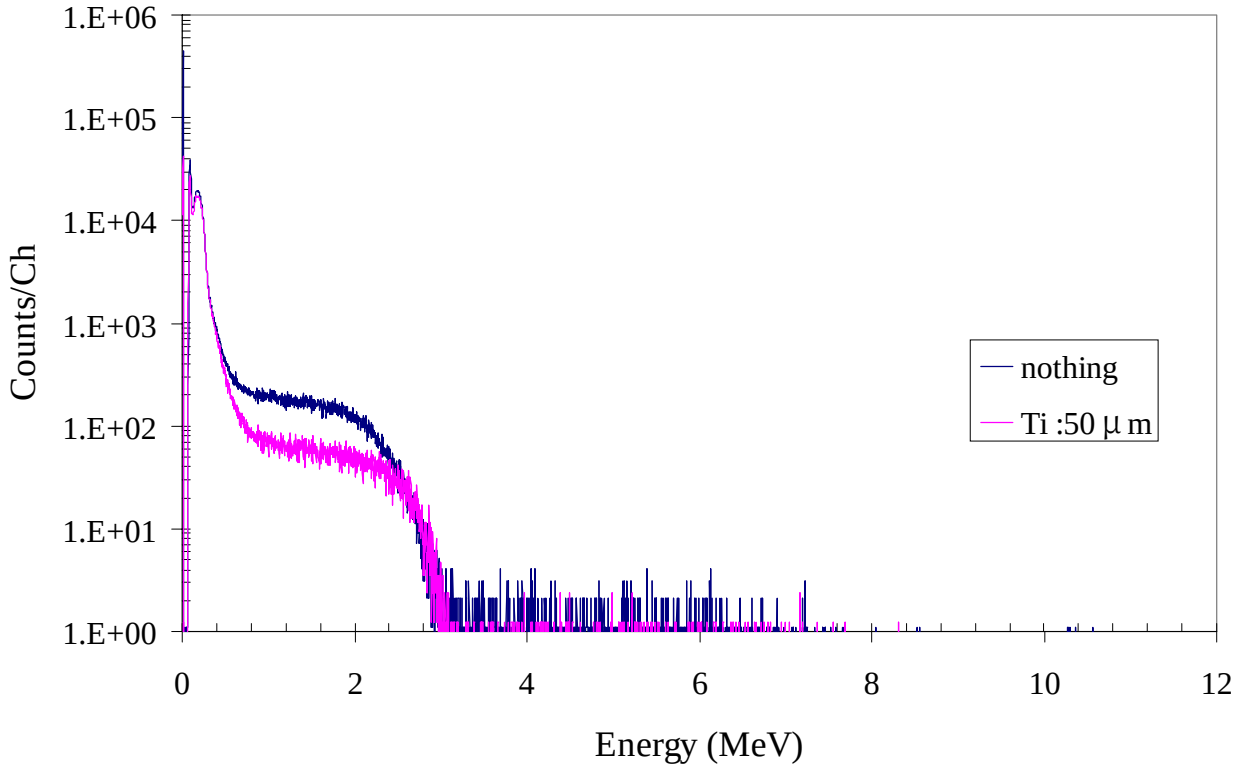


Fig.11:Charged-particle spectra observed by 60deg. Si-SSD emitted from TiDx sample implnated with 300keV deuteron beam

The kinetic energy of spectrum A is equal to all spectra. So, we considered that spectrum A was the neutron response.However, the yield of spectrum A which is recorded by nothing screening foil is much than that using titanium 50 μm.

Much of the spectrum A is occupied neutron response, but there is another charged-particle signal.

Spectrum B

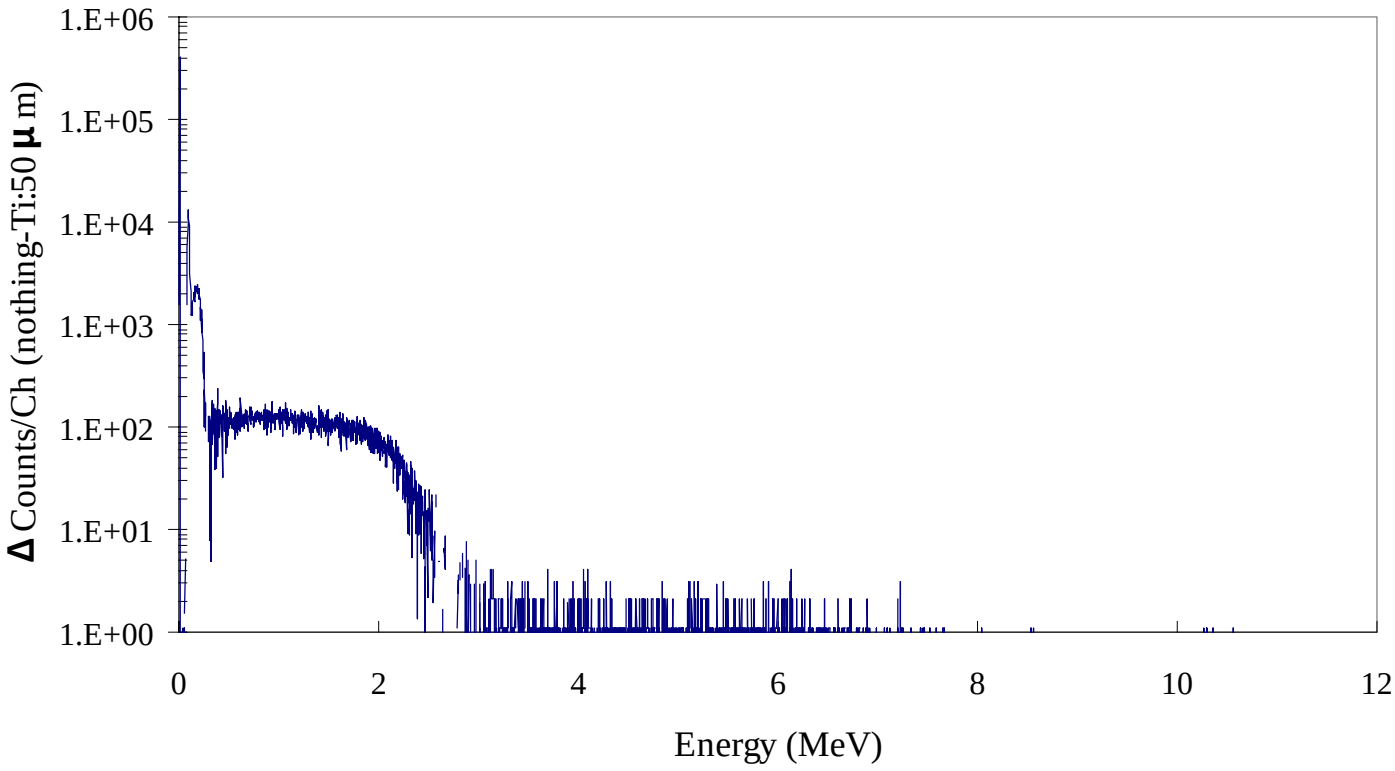


Fig.12:This figure is counts difference between the counts of screening foil nothing and that of the Ti foil which is 50 μ m thickness.

We consider that spectrum B suggests 3D multi-body fusion from Fig.12. But, there is the possibility that spectrum B is impurity reaction, because the neutron which reach to Si-SSD decrease by setting the metal foil in front of Si-SSD.

Conclusion

- The spectrum which suggests multi-body fusion is observed by 60 degree Si-SSD.
- We know that the most part of spectrum A is occupied neutron response by the experiments of using screening foil. But, the yield of using screening foil differ from that of no using. So, the possibility that the spectrum besides neutron response is observed suggests.
- spectrum B was not observed at coincidence measurement. But, it is observed by 60 degree Si-SSD. The possibility that it is the deuteron of multi-body fusion suggests.

Future Work

- Another multi-body fusion branch(1) and the transition of $^{6}Li^{*}$(the virtual compound nucleus of 3D multi-body fusion) considered, we will verify the spectrum observed by 60 degree Si-SSD .

$3D \rightarrow n + p + {}^{4}He + 20.1MeV$.....(1)

- We will try the coincidence measurement adjusting solid angle.
- We will verify the impurity reaction expected occurring in Si-SSD