



INTERESTING STATES IN $A=10$ MASS REGION, POPULATED IN $^{10}\text{B} + ^{10}\text{B}$ NUCLEAR REACTIONS

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NUCLEI AROUND A=10

- Shell model states
- Cluster states
- Nuclear molecules
- Bose-Einstein condensates
- ...

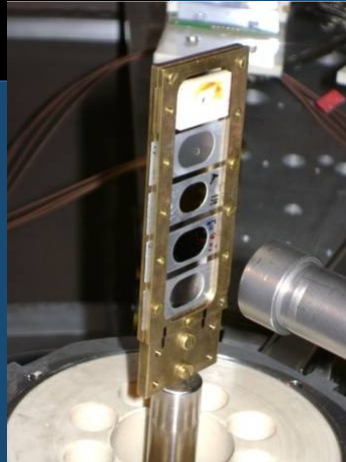
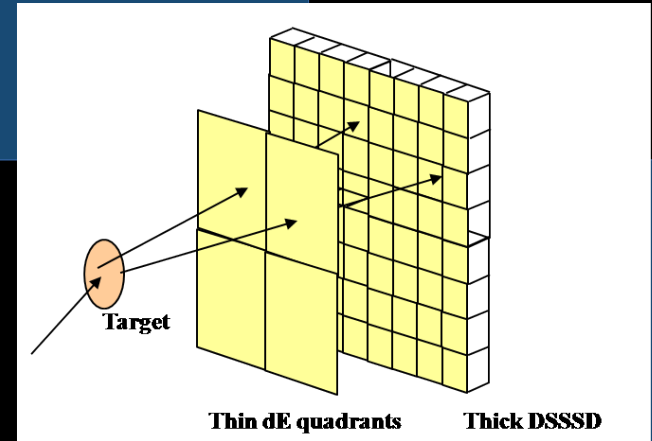
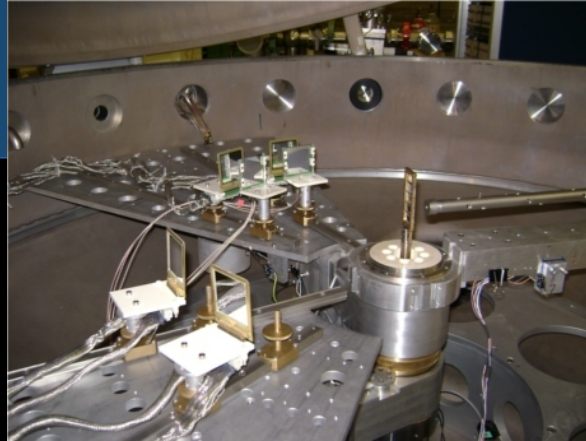
^{10}B : spin 3^+ in the ground state!

				12O	13O	14O	15O	16O	17O
			10N	11N	12N	13N	14N	15N	16N
		8C	9C	10C	11C	12C	13C	14C	15C
	6B	7B	8B	9B	10B	11B	12B	13B	14B
	5Be	6Be	7Be	8Be	9Be	10Be	11Be	12Be	13Be
3Li	4Li	5Li	6Li	7Li	8Li	9Li	10Li	11Li	12Li
	3He	4He	5He	6He	7He	8He	9He	10He	
1H	2H	3H	4H	5H	6H	7H			

Ivano Lombardo (INFN - Catania, Italy) - Analysis of excited states in ^{13}C and their cluster structure

$^{10}\text{B} + ^{10}\text{B}$ MEASUREMENT

Beam: ^{10}B , 4+, $I \approx 5 \text{ nA}$
Energy: 50 and 72.2 MeV



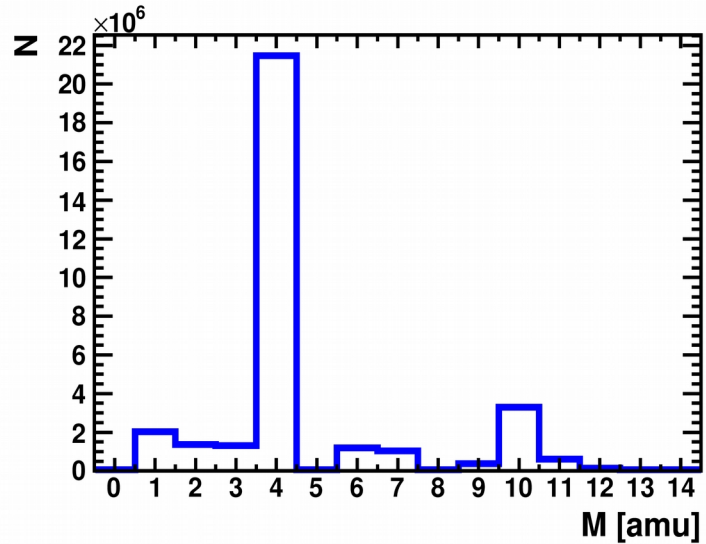
3 detector setups:

40° , 20° , 30° , 50°

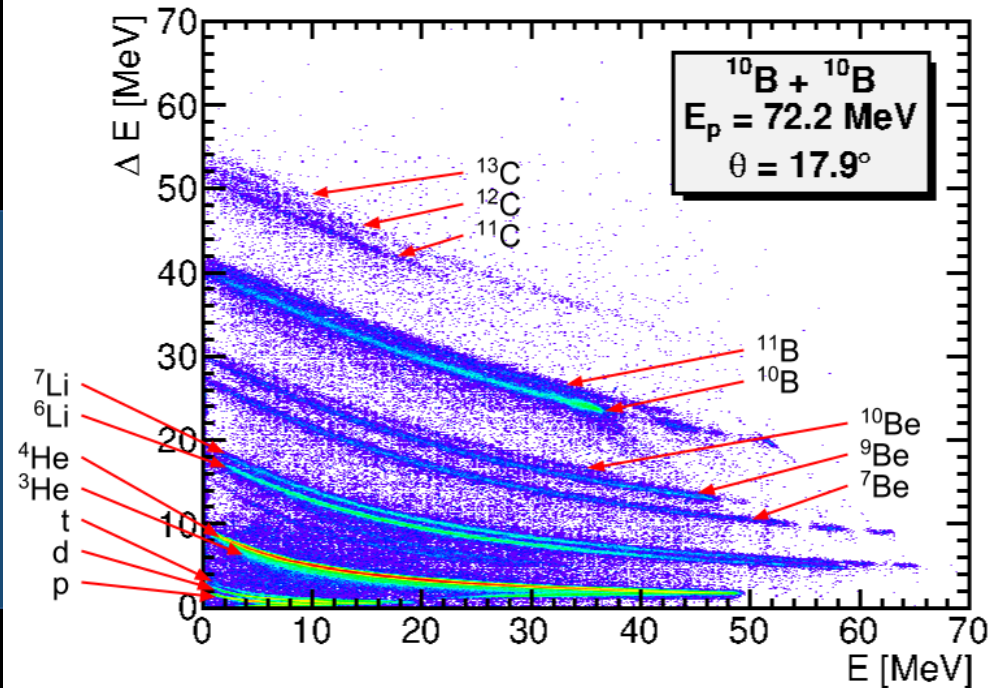
40° , 20° , 20° , 40°

46° , 26° , 33° , 53°

SELECTED RESULTS

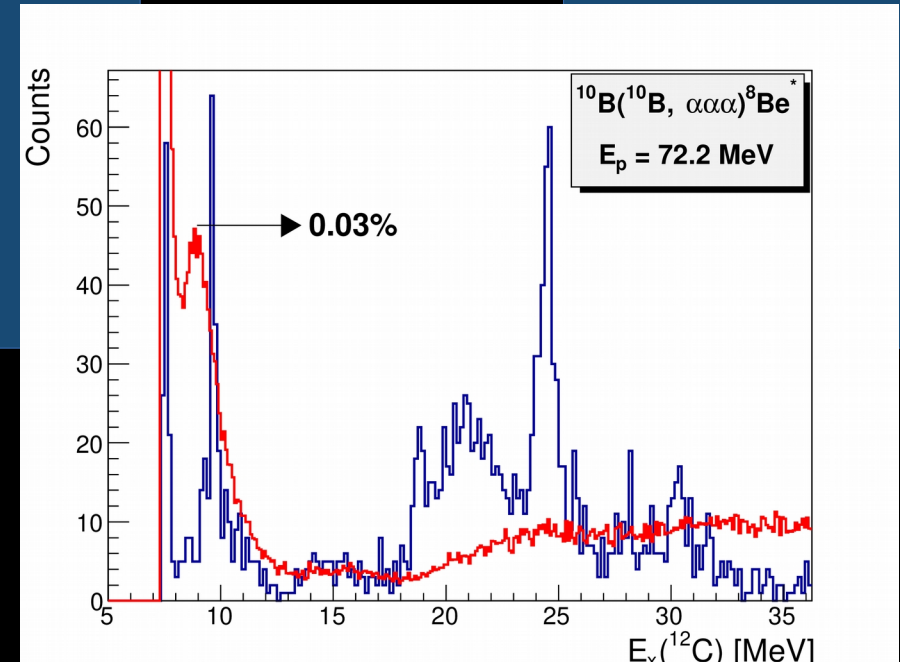
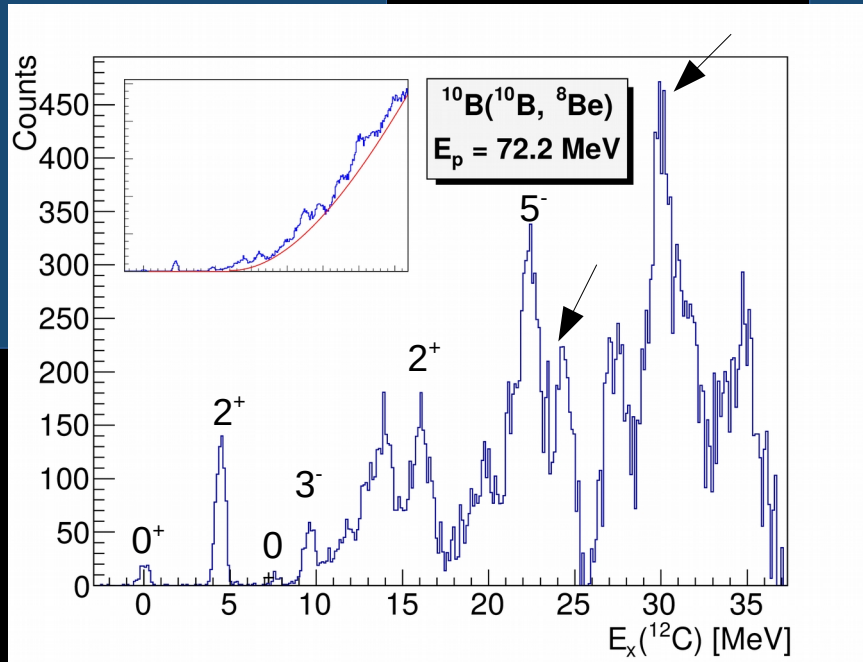
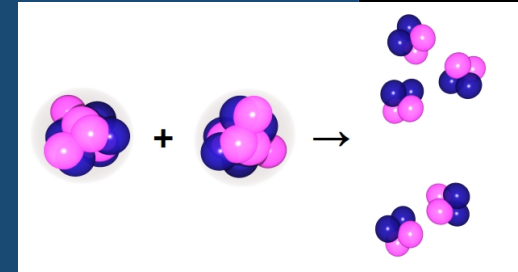


- nuclei from ^1H up to ^{13}C detected
- at both beam energies the number of detected α -particles was remarkably higher than any other detected nuclei
- double and triple α -particle coincidences



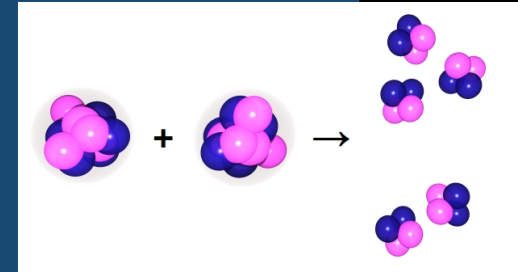
RESULTS FOR ^{12}C

A coincident detection of **three α -particles** enabled reconstruction of the $^{10}\text{B} + ^{10}\text{B} \rightarrow 5\alpha$ reaction, and associated ^{12}C spectra of intermediate states

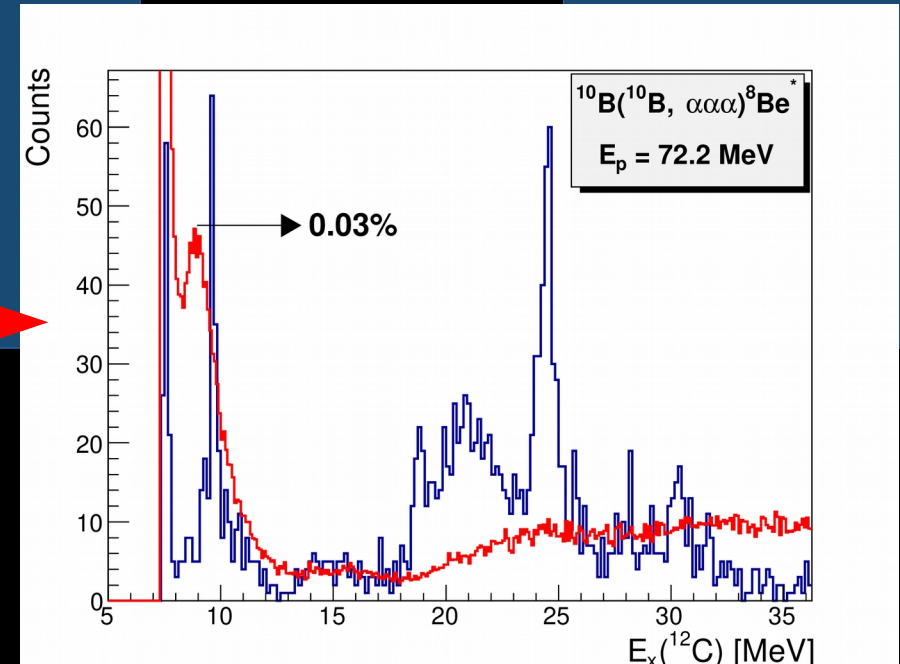


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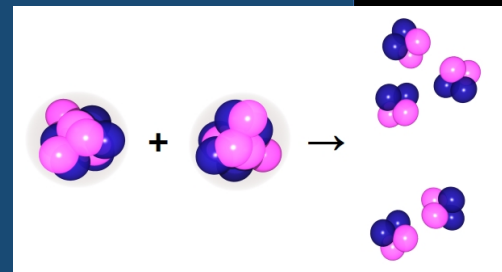


A new state at $E_x = 24.4 \text{ MeV}$ was strongly populated, showing properties similar to the well known 3^- state at $E_x = 9.64 \text{ MeV}$

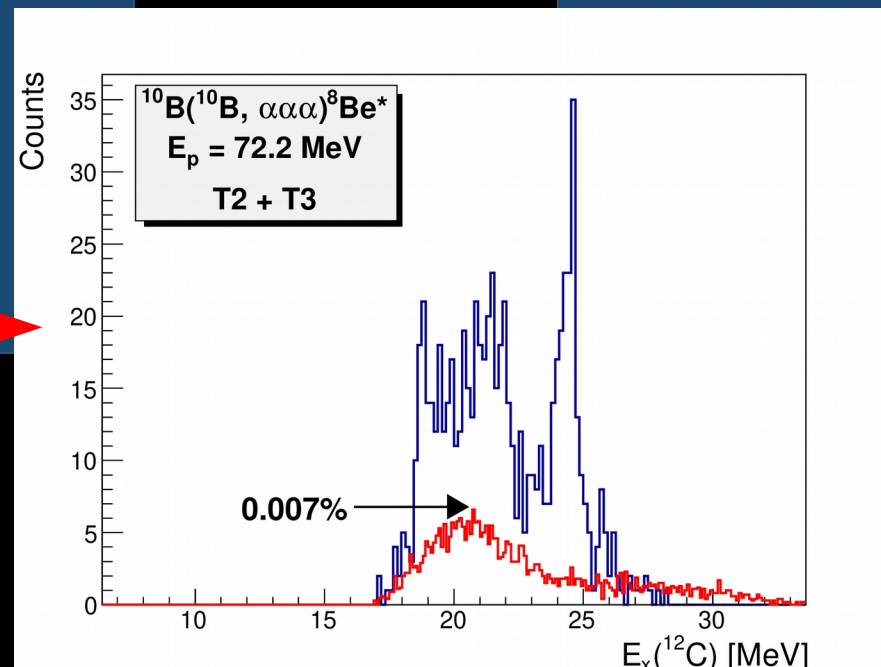


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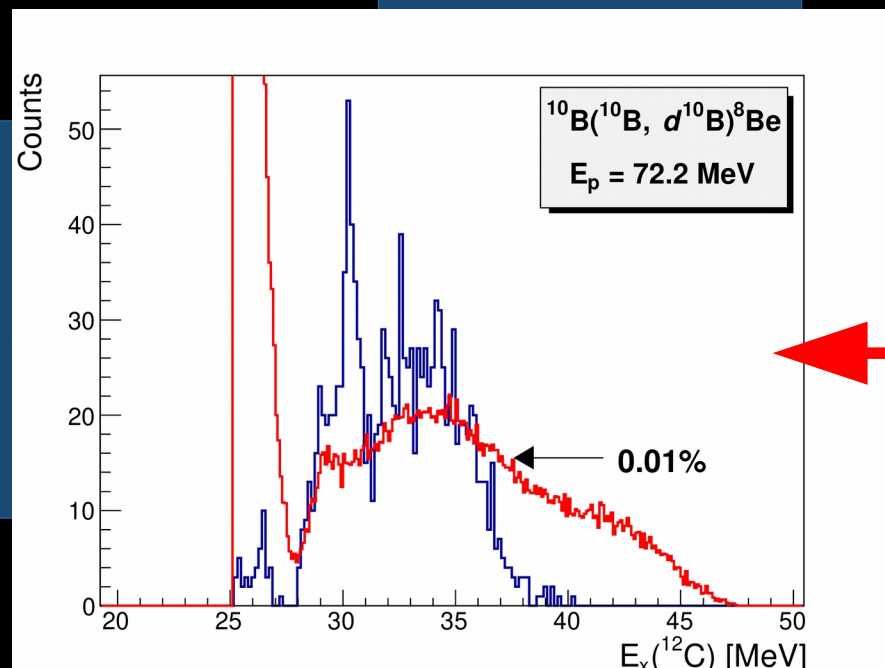
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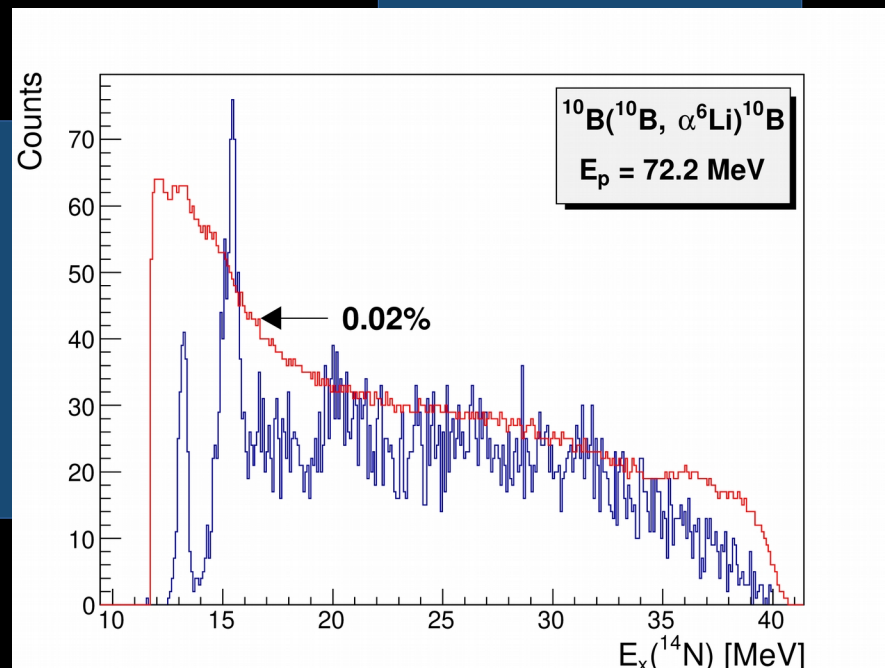


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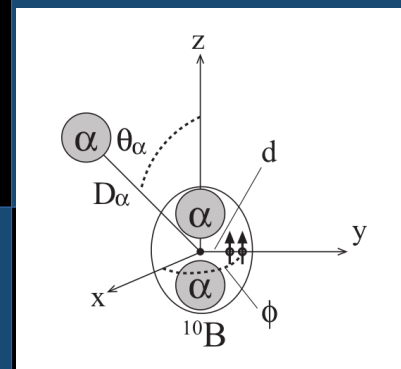


Rarely seen state at $E_x = 30.3 \text{ MeV}$ is found to be strong in the $d + ^{10}\text{B}$ decay channel, reinforcing the previous suggestions that it has the exotic $2\alpha + 2d$ molecular structure

RESULTS FOR ^{14}N

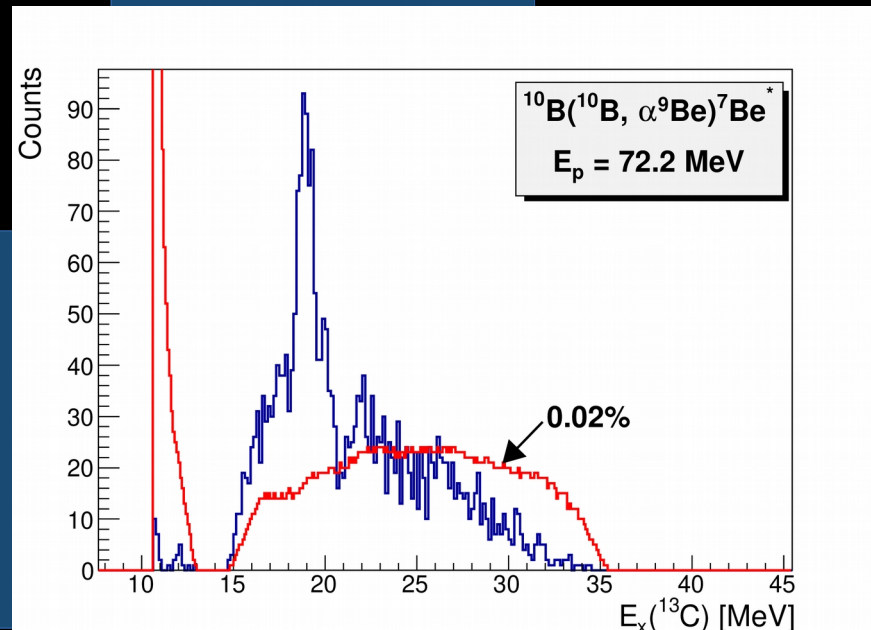
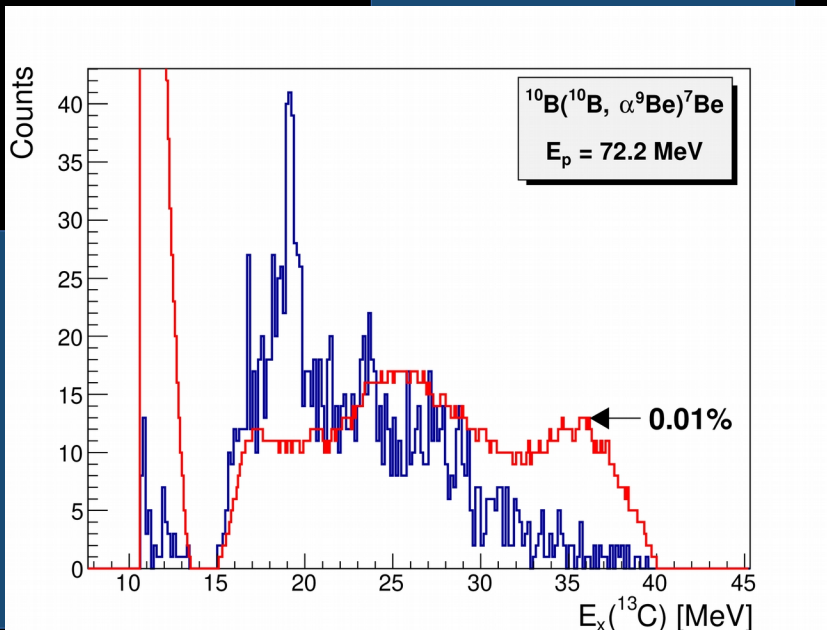


In four nucleons transfer reaction channel, excited states of the ^{14}N at $E_x = 13.2$ and 15.39 MeV were measured. Both of them fit nicely to a recent AMD calculations as the head and the 5^+ state of the $^{10}\text{B}(3^+) + \alpha$ rotational band ($K^\pi = 3^+$).



AMD calculation: Y. Kanada En'yo,
 Phy. Rev. C 92, 064326 (2015)

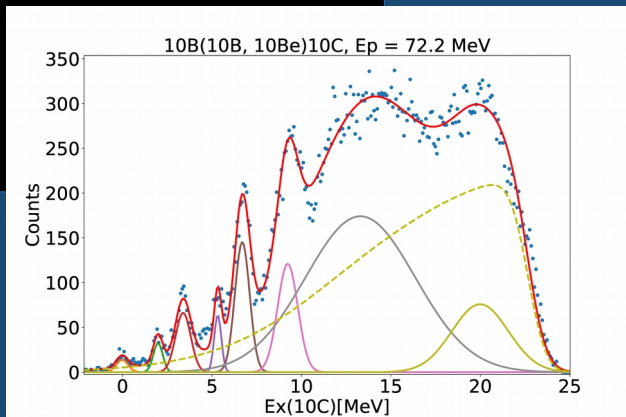
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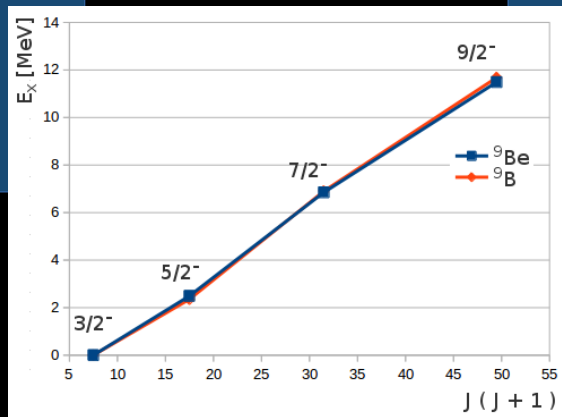
A very strong α -decaying state is seen at the $E_x = 18.9 \text{ MeV}$ in ^{13}C . This state has pronounced $^9\text{Be} + \alpha$ structure, and is a good candidate for molecular state with one valence nucleon orbiting around 3 α centers.

AND MANY OTHER CHANNELS...

^{10}C

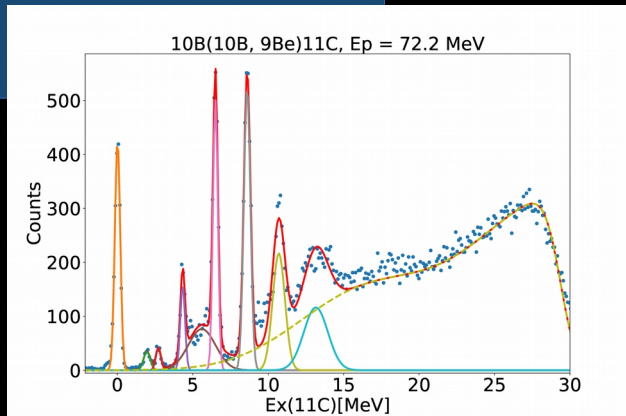


^9Be , ^9B

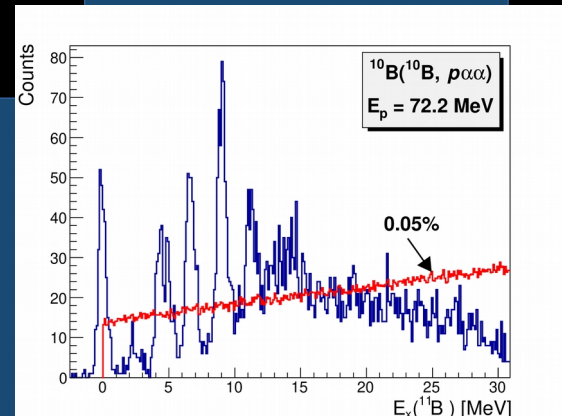


States that nicely fit into ground state rotational bands of ^9B and ^9Be these nuclei are clearly observed as their $9/2^-$ members.

^{11}C



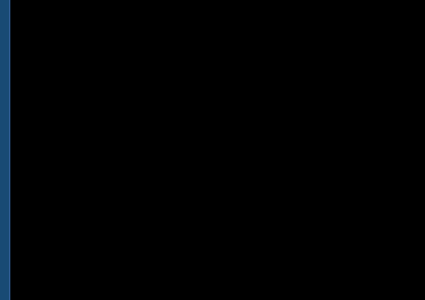
^{11}B



The most interesting states in ^{11}B and ^{11}C inclusive spectra are **10.74 MeV in ^{11}C** and **11.42 MeV in ^{11}B** , which are populated in one nucleon transfer reaction for the first time.

SUMMARY AND OUTLOOK

- Results were obtained for the $^{8,9}\text{Be}$, $^{9,10,11}\text{B}$, $^{10,11,12,13}\text{C}$, ^{14}N , and ^{16}O nuclei
- Analysis of another experiment: $^7\text{Be} + ^{6,7}\text{Li}$ on $E = 45\text{MeV}$ beam
- Future experiments to reveal characteristics of the new states populated here



**THANK YOU FOR
YOUR ATTENTION!**

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