The 4rd International Conference on Particle Physics and Astrophysics

Spectroscopy of 7He in reactions of stopped pion absorption by nuclei 12,14C

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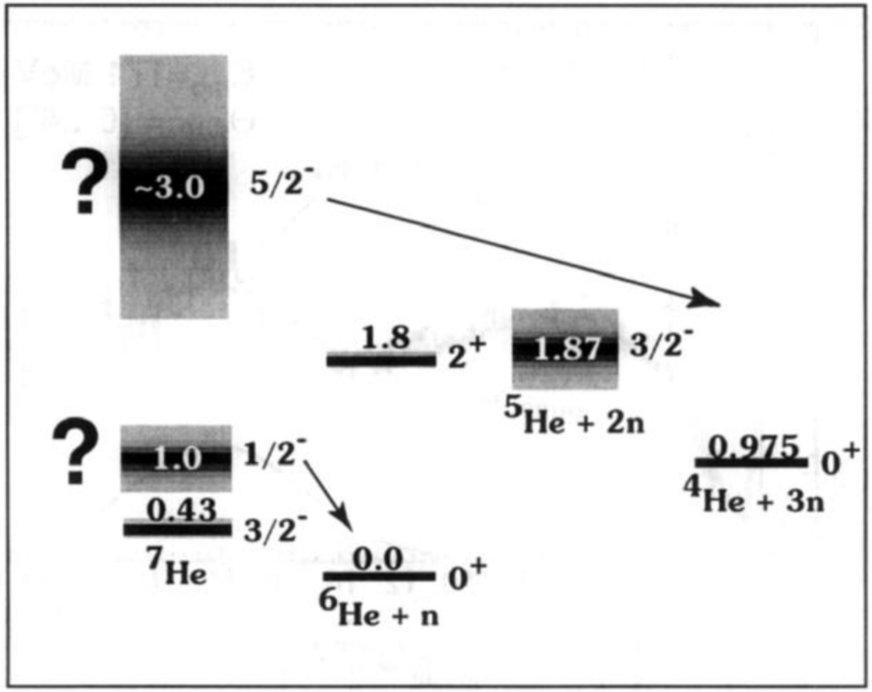
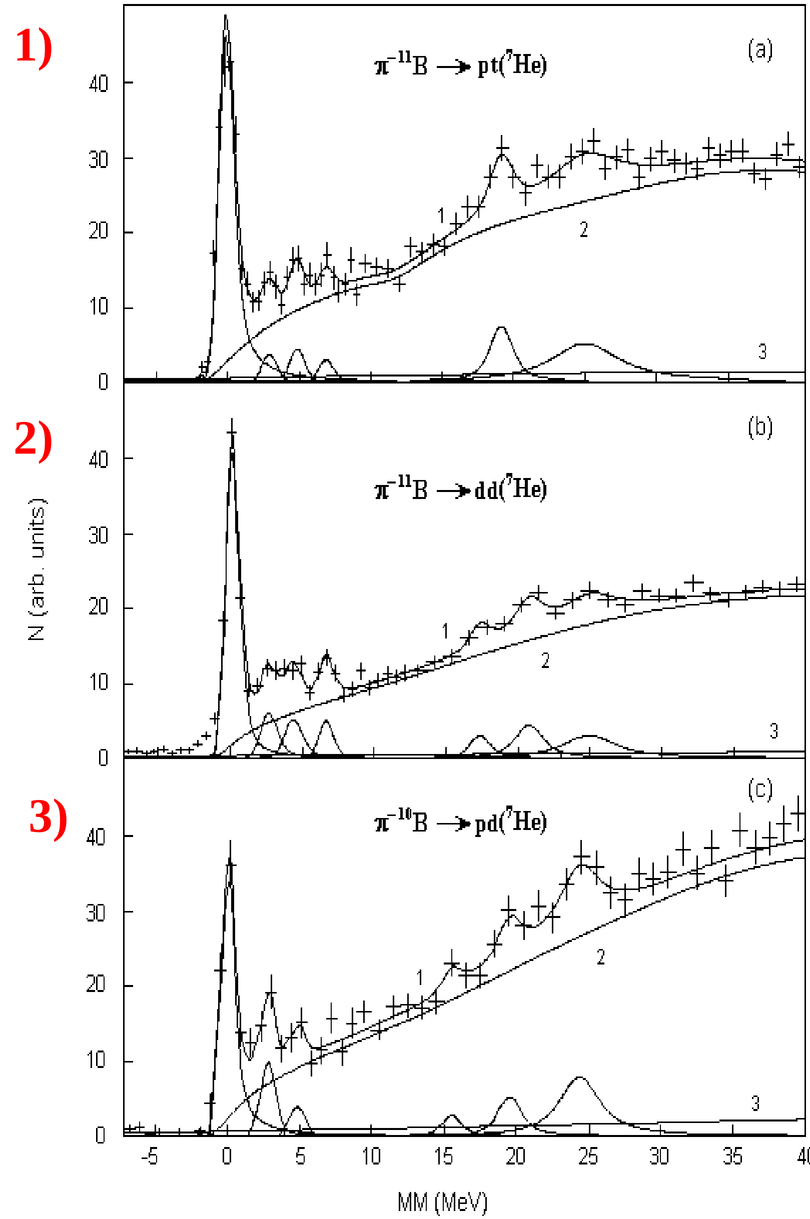
Heavy Helium Isotope ^{7}He

The ground state of ^{7}He is a resonance system comprising the ground state of $^{6}He_{g.s.}$ and a neutron in the $1p_{3/2}$ orbital. This state is unbound relative to decay into ^{6}He and a neutron at 0.410±0.008 MeV and has a width Γ = 0.15±0.02 MeV. Results of recent works give lower values of the resonance energy 0.35 ÷ 0.40 MeV.



Level Structure of ^{7}He

E_x, MeV	Γ, MeV	Our data	Work
g.s.	-	1), 2), 3)	[1]
0.6(1)	0.75(8)		[2]
0.9(5)	1.0(9)		[3]
≈ 1.45	≈ 2		[4]
≈2.6	≈2		[5]
2.9(3)	2.0(3)		[6]
2.92(9)	1.99(17)		[1]
3.1(1)	≤ 0.5	1), 2), 3)	
4.9(2)	≤ 0.5	1), 2), 3)	
5.8(3)	4(1)		[7]
6.7(2)	≤ 0.5	1), 2)	
≈8.0	~7		[8]
16.9(5)	1.0(3)	2), 3)	
≈18.0	~7		[8]
18.0(1.5)	~10		[9]
19.8(3)	1.5(3)	1), 2), 3)	
20(1)	9(2)		[10]
24.8(4)	4.6(7)	1), 2), 3)	



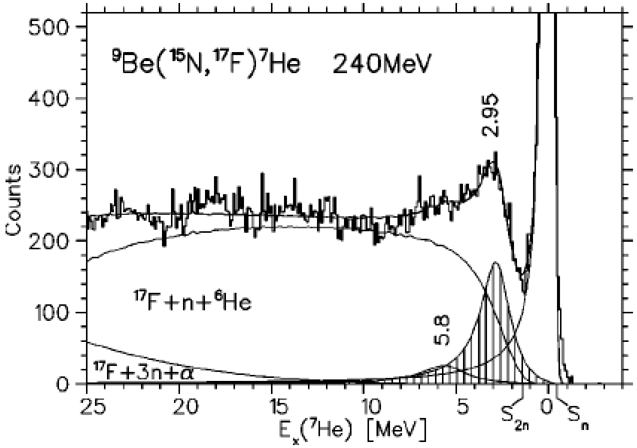
the decay threshold $^7He \rightarrow t+t+n$ (12.3 MeV)

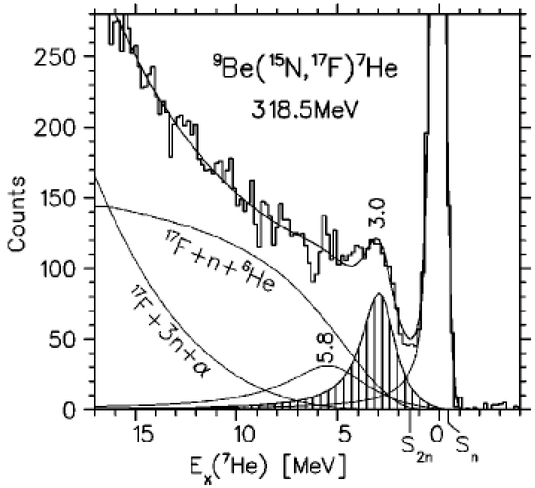
Theoretical Predictions

J^P		Works									
		[85] 1990	[86] 1997	[87] 1998	[69] 2004	[67] 2005	[66] 2005	[93] 2006	[6] 2007	[7] 2009	[94] 2013
$7/2^-$	E_x							1.27			
	Γ							*0.03*			
$1/2^-$	E_x	2.49	2.9	2.3	2.9	3.27	0.37	2.36	1.05	0.6~1.2	1.68
	Γ				*3*	*2.7*	*7.98*	*4.1*	*2.19*	*1.0~1.4*	*2.89*
$5/2^-$	E_x	3.52	4.7	3.7	3.3	3.9	2.73	3.12	3.25	~2.5	2.42
	Γ				*2*	*0.94*	*1.78*	*0.2*	*1.5*	*~0.5*	*1.07*
$3/2^-$	E_x	4.68		4.4	3.8	5.2	2.41	5.81	3.37		
	Γ				*2*	*1.2*	*3.9*	*1.9*	*1.95*		
$3/2^-$	E_x				7.1	10.5	3.83		5.32		
	Γ					*21*	*6.1*		*5.77*		

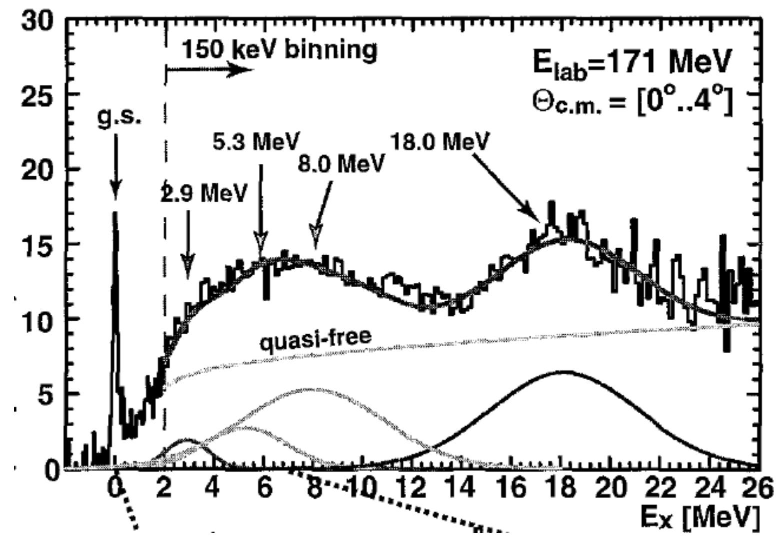
85. Wolters A.A. et al. Phys. Rev. C. 1990. 42. 2062.
86. Wurzer J. and Hofmann H.M. Phys. Rev. C. 1997. 55. 688.
87. Navratil P. and Barrett B.R. Phys. Rev. C. 1998. 57. 3119.
69. Pieper S.C. et al. Phys. Rev. C. 2004. 70. 054325.
67. Volya A. and Zelevinsky V. Phys. Rev. Lett. 2005. 94. 052501.
66. Hagen G. et al. Phys. Rev. C. 2005. 71. 044314.
93. Canton L. et al. Phys. Rev. C. 2006. 74. 064605.
6. Myo T. et al. Phys. Rev. C. 2007. 76. 054309.
7. Arai K. and Aoyama S. Phys. Rev. C. 2009. 80. 027301.
94. Baroni S et al. Phys. Rev. C. 2013. 87. 034326.

4 MeV < E_x < 8 MeV





E_x, MeV	Γ, MeV	J^P	Our measurem.	Work
4.9(2)	≤ 0.5		1), 2), 3)	
5.8(3)	4(1)			[7]
6.7(2)	≤ 0.5		1), 2)	
≈8.0	~7			[8]

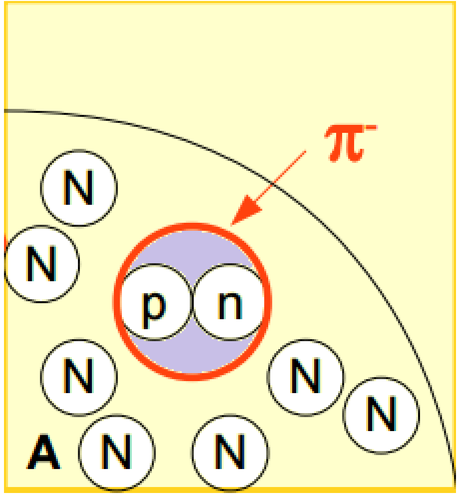


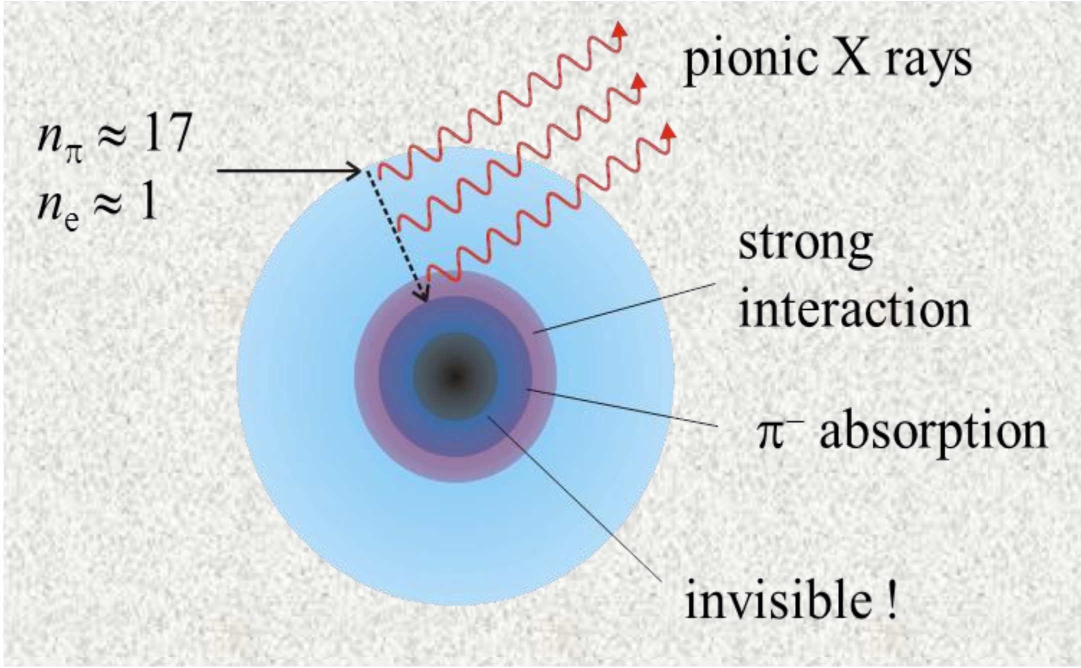
[8] ***Frekers D.*** **// Nucl. Phys. A 2004. V.731. P. 76.**
^{7}Li(d,^{2}He)^{7}He E = 171 MeV

7. H. G. Bohlen *et al.*, Phys. Rev. C 64, 024312 (2001).
^{9}Be(^{15}N,^{17}F)^{7}He E = 240 and 318.5 MeV

Stopped pion absorption by nuclei – Tool for production of neutron-rich states

$\pi^- + {}^9Be, {}^{10,11}B, {}^{12}C \rightarrow$ exotic nuclei + X





$\pi^- + pn\ (T=0, S=1, l_{pn}=0) \rightarrow nn$

$\pi^- + pp \rightarrow pn$

$\pi^- + pp \rightarrow np \rightarrow p$

$\downarrow$

$n+d \rightarrow t$

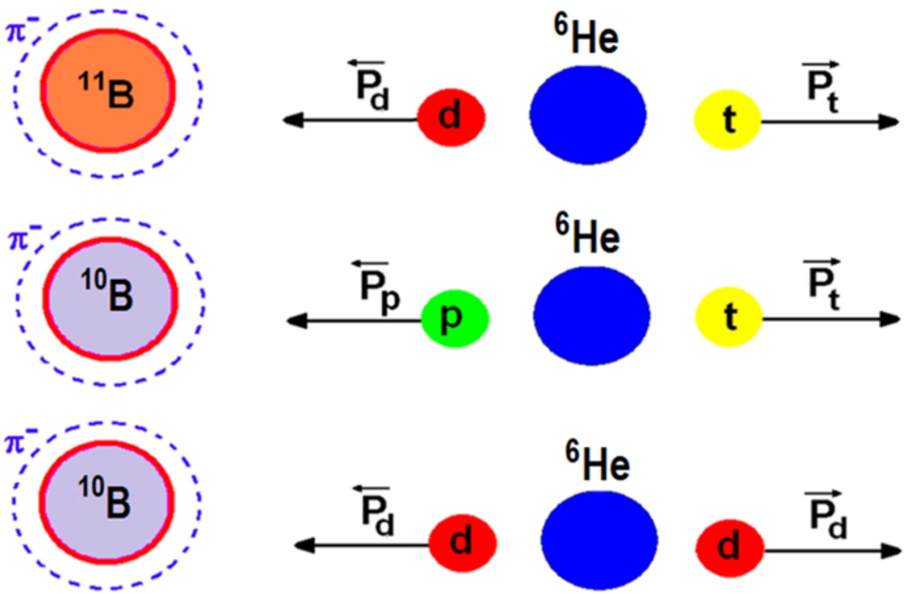
Cluster absorption

$\pi^- + {}^4He \rightarrow nt$ $\quad$ $\pi^- + {}^4Li \rightarrow pt$

Secondary pick-up

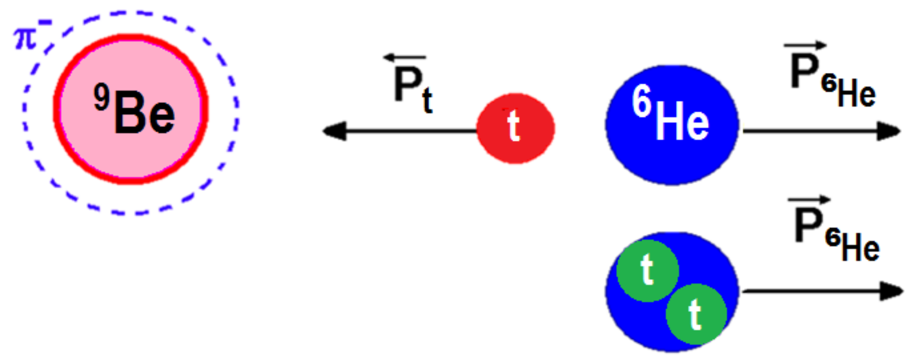
Stopped pion absorption by nuclei – Tool for production of neutron-rich states

Three-body channels



$P_R \sim 100$ MeV/c

Two-body channels



$P_R \sim 500 \div 700$ MeV/c

Layout of spectrometer (LAMPF)

Beam	Target	Sizes and Impurities	Stop rate, 1/s	SCD- telescopes	Threshold(MeV)
$E\pi$= 30 MeV ($\Delta p/p=\pm1\%$)	^{9}Be $^{10,11}B$ $^{12,14}C$	Thickness – 25 mg/sm^2, (135μm), diameter – 26 mm,	~ $6\cdot10^4$	2 Si(Au) -T=100, 450μm 14 Si(Li) -T=3 mm, Wd≈0.1mm S=8 mm^2 Ω=55÷15 mster	$E_p \approx 3.5$, $E_d \approx 4$, $E_t \approx 4.5$, $E_{He} \approx 15$.

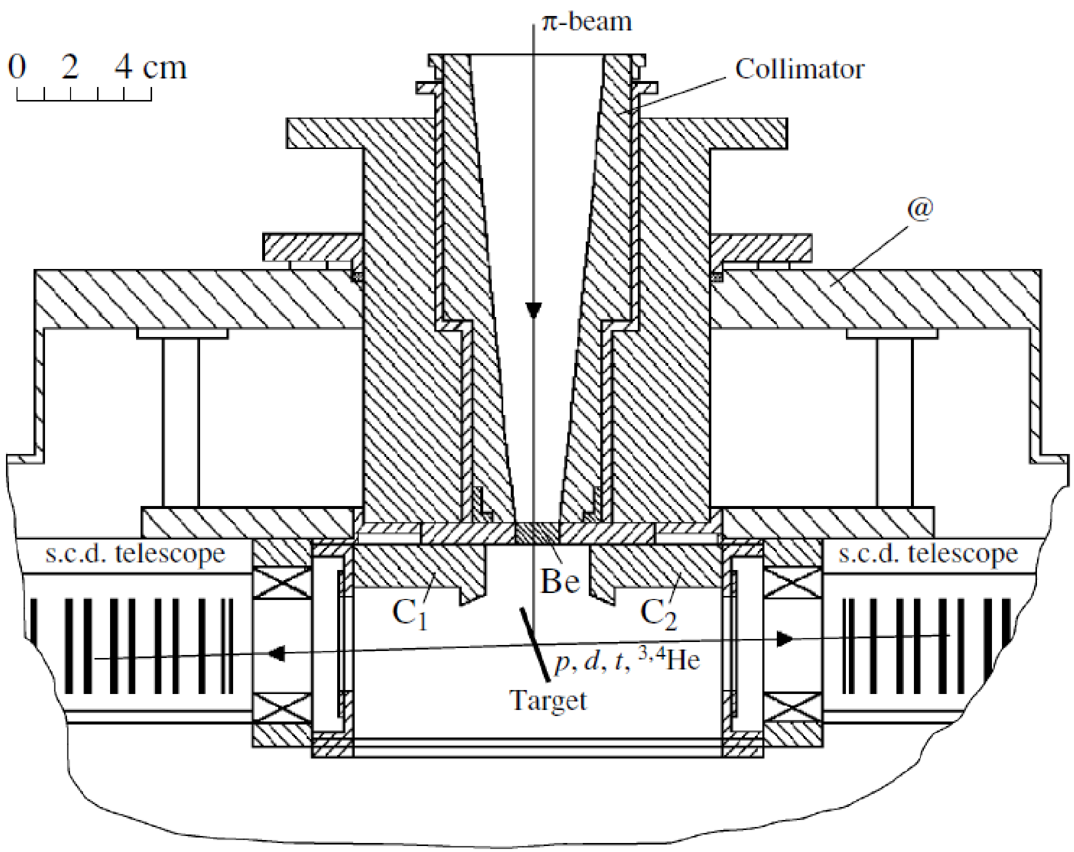
FWHM

ΔE < 0.5 MeV (Z=1)

ΔE < 2.0 MeV (Z=2)

ΔMM < 1 MeV (Z_1=1, Z_2=1)

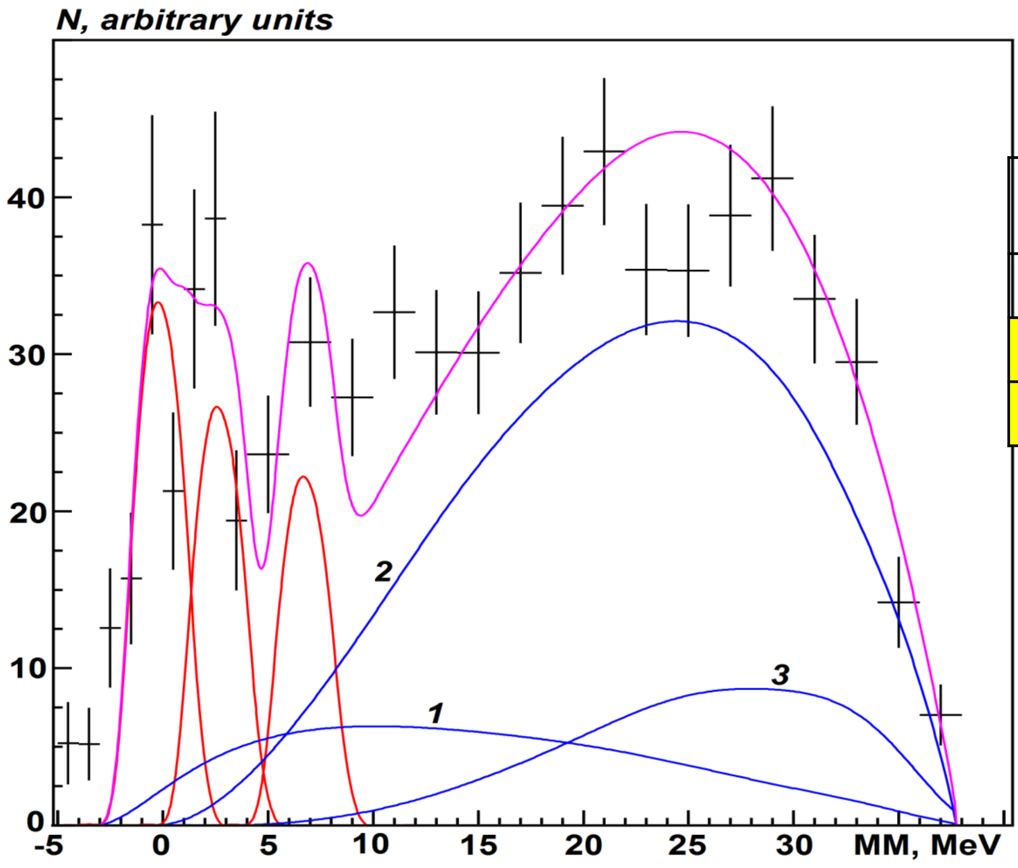
ΔMM < 3 MeV (Z_1=1, Z_2=2)



•*Gornov M. G. et al.* // Nucl. Inst. and Meth. in Phys. Res. A 2000. V. 446. P. 461.

^{7}He production on the ^{12}C target

$\pi^{-}\,{}^{12}C \rightarrow p\,{}^{4}HeX$



E_x, МэВ	Г, МэВ
g.s.	0.6±0.2
2.9 ± 0.3	< 2
≈ 7	< 1

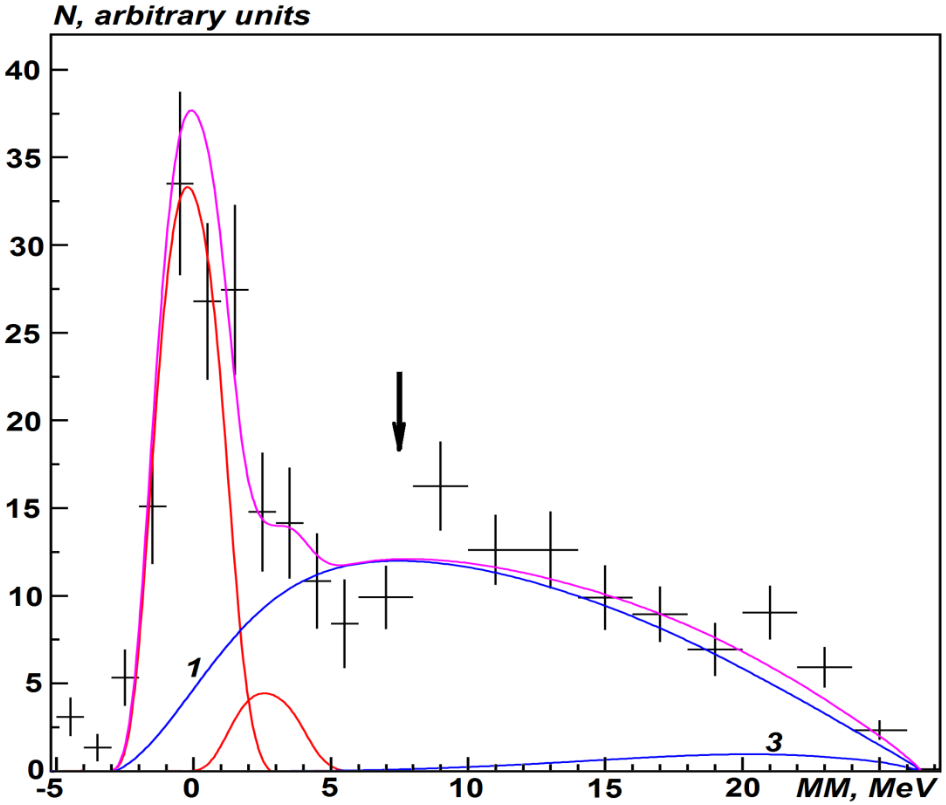
1-Phase volume $\pi^{-}\,{}^{12}C \rightarrow p\,{}^{4}He\,{}^{6}He\,n$

2-Phase volume $\pi^{-}\,{}^{12}C \rightarrow p\,{}^{4}He\,{}^{5}He\,2n$

3-Phase volume $\pi^{-}\,{}^{12}C \rightarrow p\,{}^{4}He\,{}^{4}He\,3n$

^{7}He production on the ^{12}C target

$\pi^- \, ^{12}C \rightarrow d^3HeX$



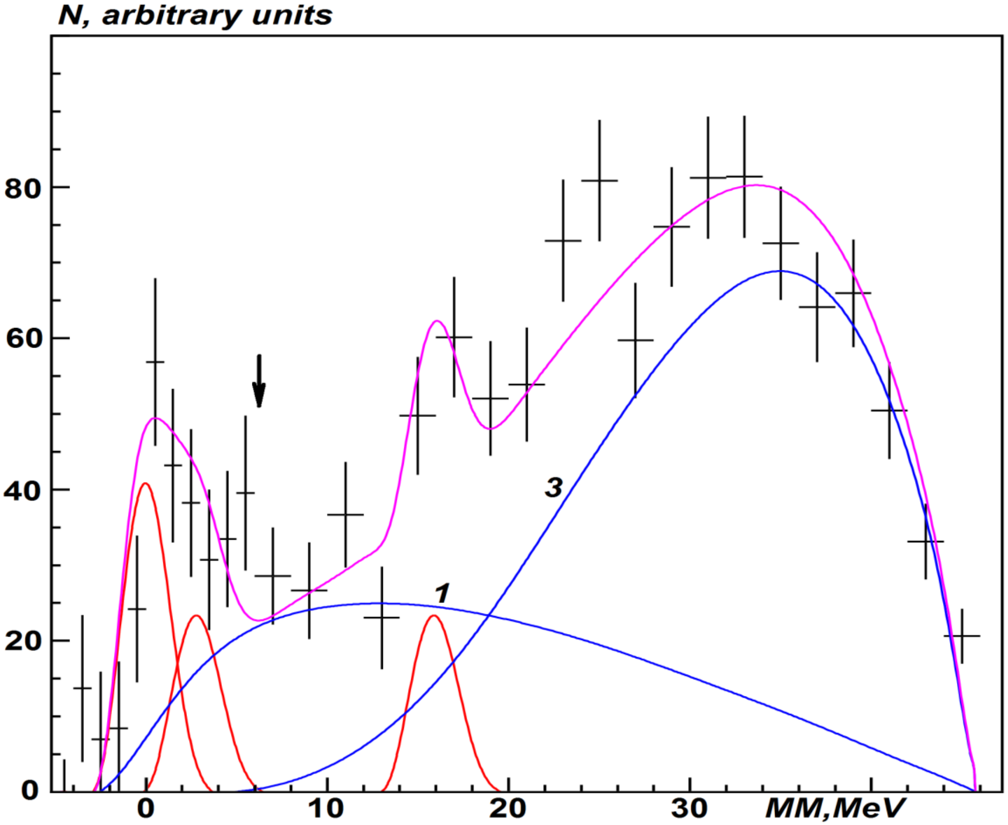
E_x, МэВ	Γ, МэВ
g.s.	0.6±0.2
≈ 2.9	< 2
??? 7	--------------

1-Phase volume $\pi^- \, ^{12}C \rightarrow d^3He^6Hen$

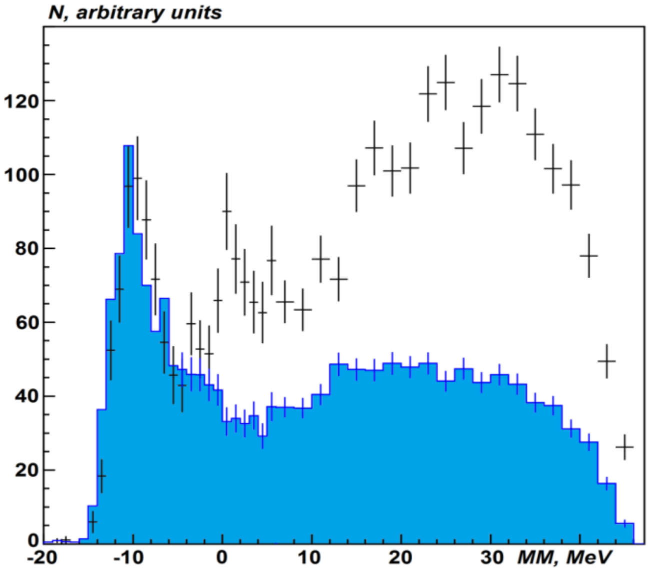
3-Phase volume $\pi^- \, ^{12}C \rightarrow p^4He^4He3n$

^{7}He production on the ^{14}C target

$\pi^- \, ^{14}C \to t \, ^4He X$



E_x, МэВ	Г, МэВ
g.s.	0.6±0.2
≈ 2.9	< 2
??? 7	-
≈ 16	< 2



77% –^{14}C 23% –^{12}C

1-Phase volume $\pi^- \, ^{14}C \to t \, ^4He \, ^6He n$

3-Phase volume $\pi^- \, ^{12}C \to t \, ^4He \, ^4He 3n$

Conclusion

• In $^{12}C(\pi^-, p^4He)^7He$ reaction the narrow (Γ ≤ 1 MэB) state with the excitation energy ≈ 7 MeV was observed.

• In $^{14}C(\pi^-, t^4He)^7He$ reaction narrow (Γ ≤ 2 MэB) state with the excitation energy ≈ 16 MeV was observed.

• These results are in agreement with the results obtained earlier in the stopped pion absorption by boron isotopes.

Thank you

for your attention!