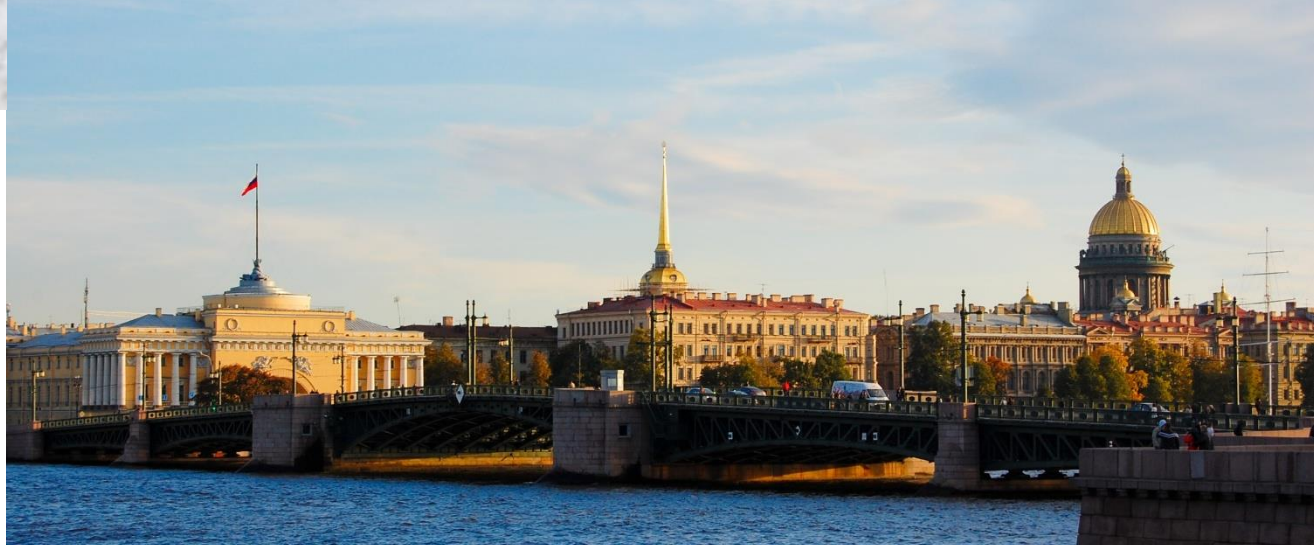

STUDY OF LEVEL STRUCTIRE OF HEAVY HELIUM ISOTOPE ^{8}He IN STOPPED PION ABSORPTION

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Heavy helium isotope ^{8}He

Among the nucleon-stable isotopes, ^{8}He has a record ratio of the number of neutrons to the number of protons: *N/Z* = 3.

In ^{8}He, the valence nucleons are more bound compared to the valence neutrons in ^{6}He (*S2n(*^{8}He) = 2.14 MeV, S2n*(*^{6}He *)* = 0.973 MeV.

A possible consequence is the coincidence of the values of the root-mean-square radii of these isotopes (*RRMS(*^{6}He *)* = 2.50 ± 0.05 fm, *RRMS(*^{8}He*)* = 2.52 ± 0.03 fm)

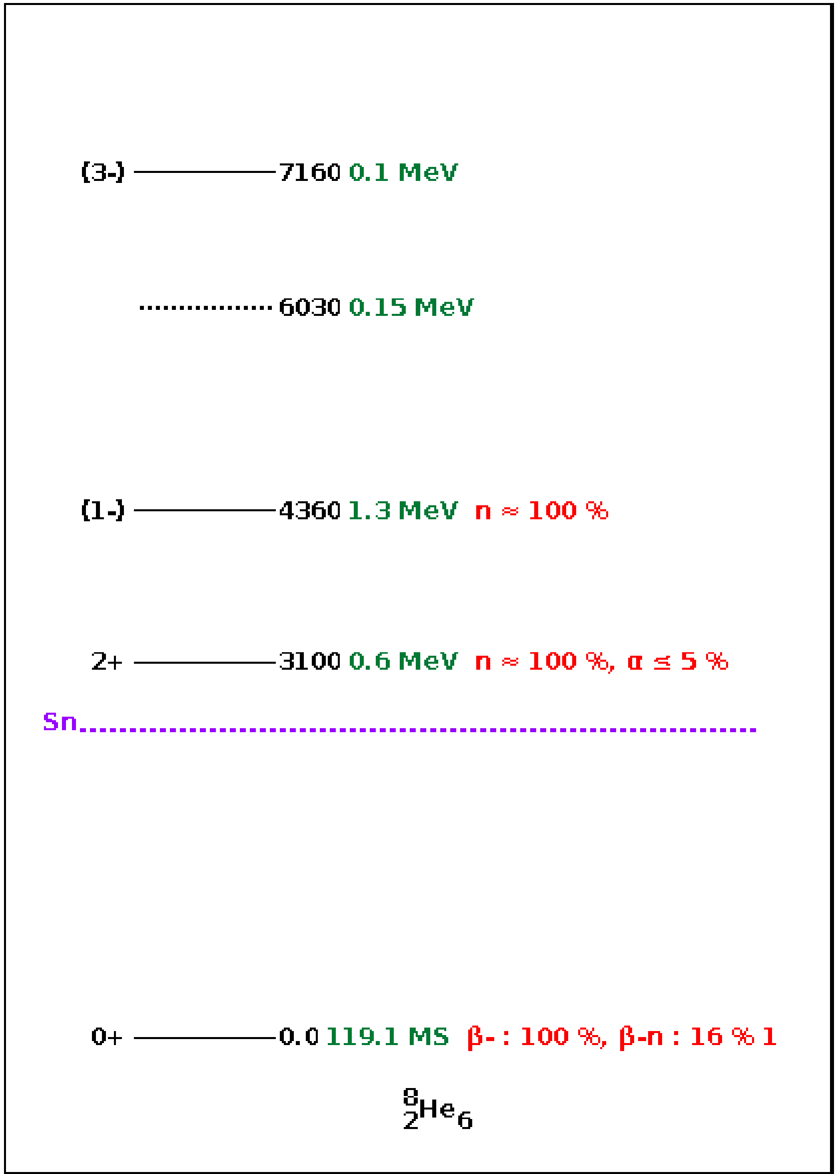
This coincidence and careful analysis of the measured cross sections for different breakup channels suggest that the structure is ^{8}He is best described as a five-body system (^{4}He+n+n+n+n*) rather than as a* two-neutron halo (^{6}He+n+n)

It was shown experimentally and theoretically, that along with the $(p3/2)^4$ component the wave function of the ground state, can contain a noticeable admixture of other components – $(p3/2)^2(s1/2)^2$, $(p3/2)^2(d3/2)^2$ and $(p3/2)^2(p1/2)^2$.

Heavy Helium Isotope ^{8}He

https://www.nndc.bnl.gov/nudat2

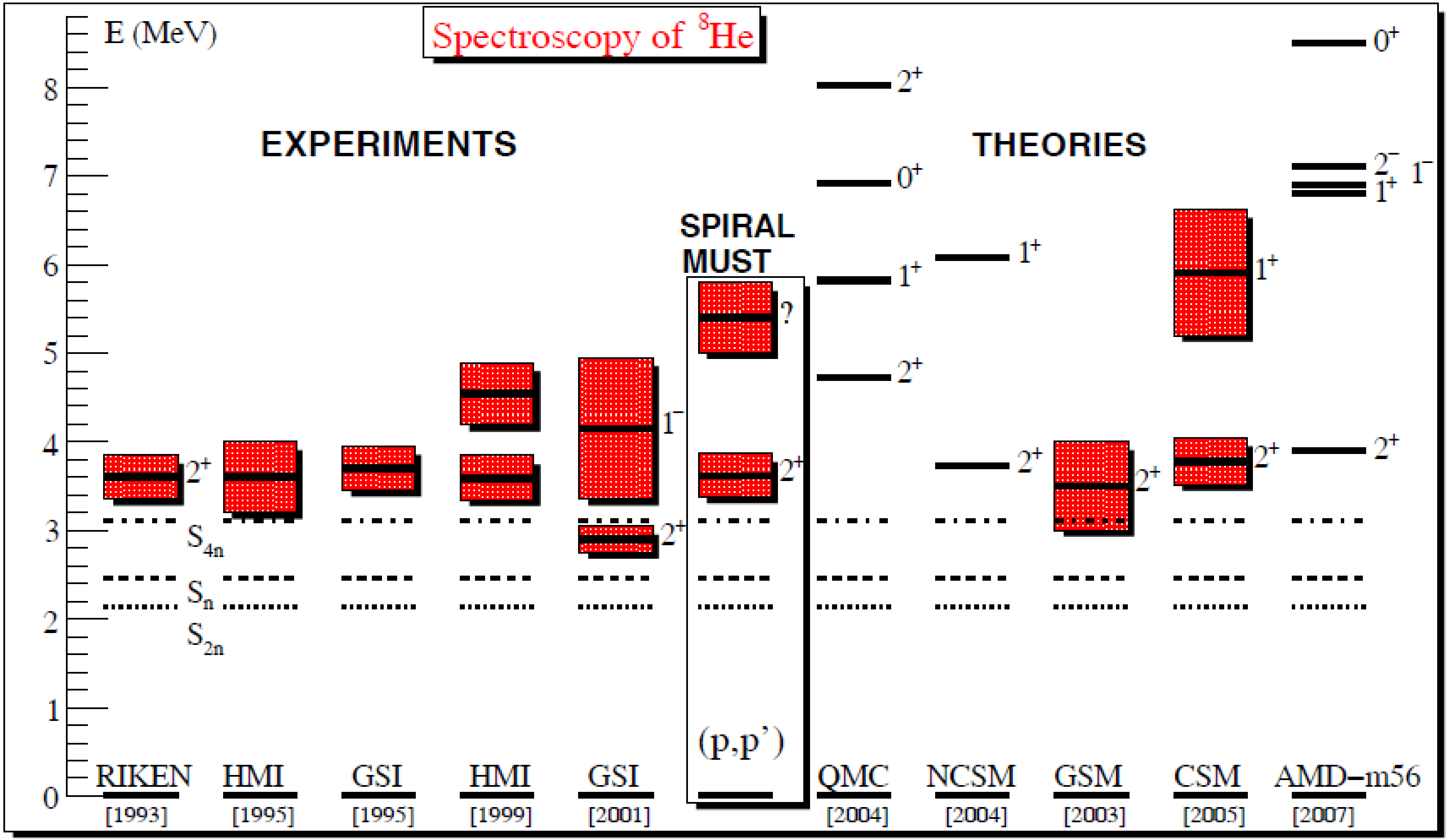
S_{2n} =2.14 MeV



Excited States of ^{8}He

E_x, MeV	Γ, MeV	J^P	work, reaction
2.6 ÷ 3.6	~0.6	2^+	[1]
4.36(20)	1.3(5)	(1^-)	
(6.03(10))	0.15(15)		
7.16(4)	0.1(1)	(3^-)	
3.62(14)	0.3(2)	2^+	[2], (p,p’)
5.4(5)	0.5(3)		
≈3		1^-	[3], (t,p)
3.6 ÷ 3.9	0.52 ÷ 0.82	2^+	
5.3 ÷ 5.5		1^+	
≈7.5			
2.99(2)	0.65(2)	2^+	[4], ^{12}C(^{8}He,^{6}Henn)X
4.14(6)	1.25(5)		

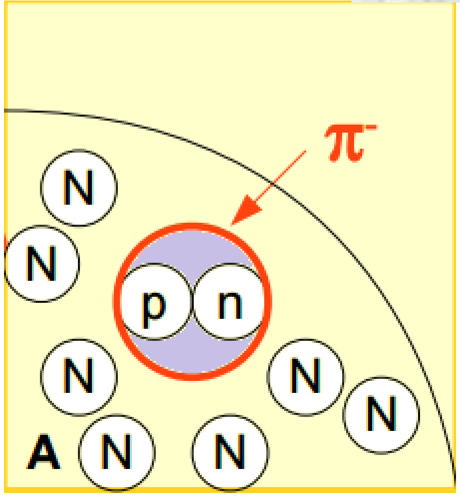
•1. Tilley D R, *et al*., 2005 *Nucl. Phys. A* 745 155.
•2. Scaza F *et al*., 2007 *Nucl. Phys. A* 788 260c.
•3. Golovkov M S *et al*., 2009 *Phys. Lett*. B 672 22.
•4. XIAO J *et al*., 2012 *Chin. Phys. Lett*. 29 082501.

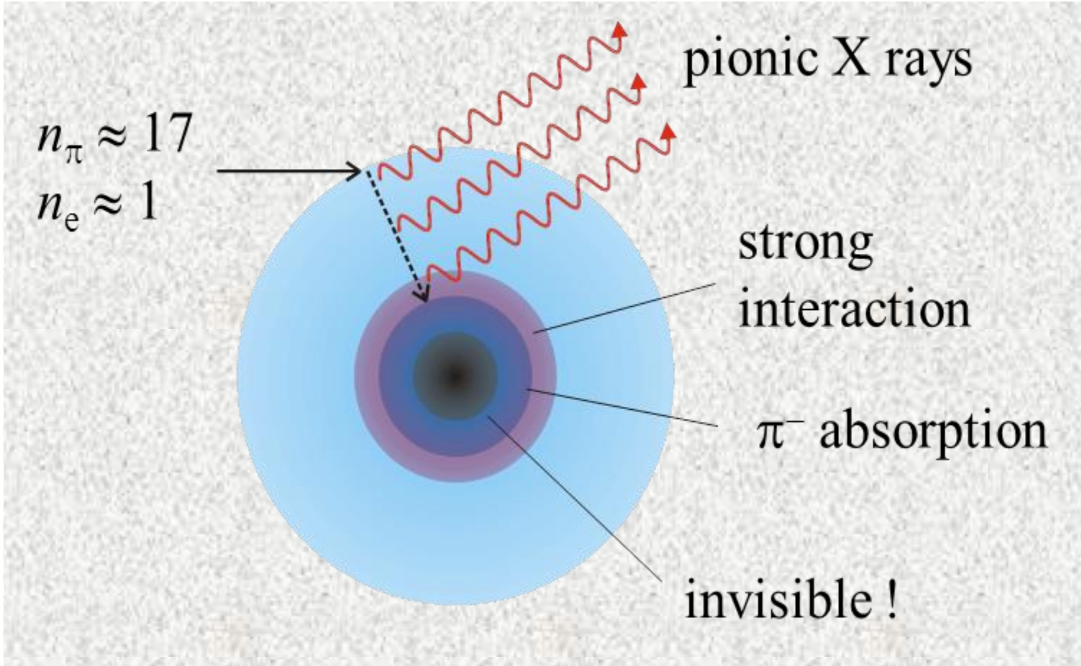


•**Lapoux V and Alamanos N, 2015 *Europ. Phys. J. A* 51 91.**

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

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





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

π^- + pp $\rightarrow$ pn

Cluster absorption

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

$\pi^- + {}^4Be$(Tetraproton) $\rightarrow p\ {}^3He$

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

$\downarrow$

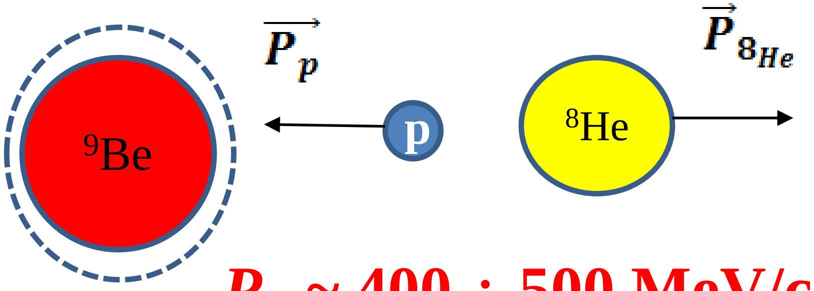
n+d $\rightarrow$ t

Secondary pick-up

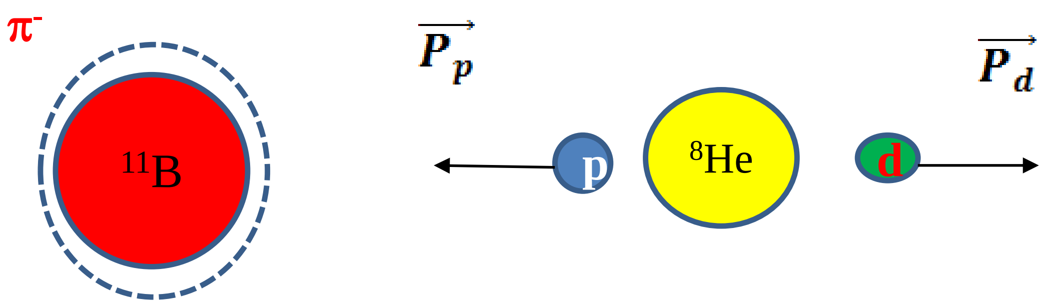
Stopped pion absorption by nuclei –
Tool for production of neutron-rich states

Three-body channels

Two-body channels



$P_R \sim 400 \div 500$ MeV/c



$P_R \sim 100 \div 200$ MeV/c

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

Advantages of the method :

Formation of residual nuclei with large neutron excess **N >> Z**

The absence of errors due to the energy resolution and the angular divergence of the beam

$E_0 = M_A + m_\pi - |B_\pi|$; $P = 0$

Large range of excited energy studied $0 \leq E_x \leq 40$ **MeV**

Opportunity to study a wide range of nuclei in a single experimental run

Disadvantages of the method :

Lack of reliable theoretical models that describe the reactions studied

It is quite difficult to determine quantum numbers of the state studied

Layout of spectrometer (LAMPF)

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

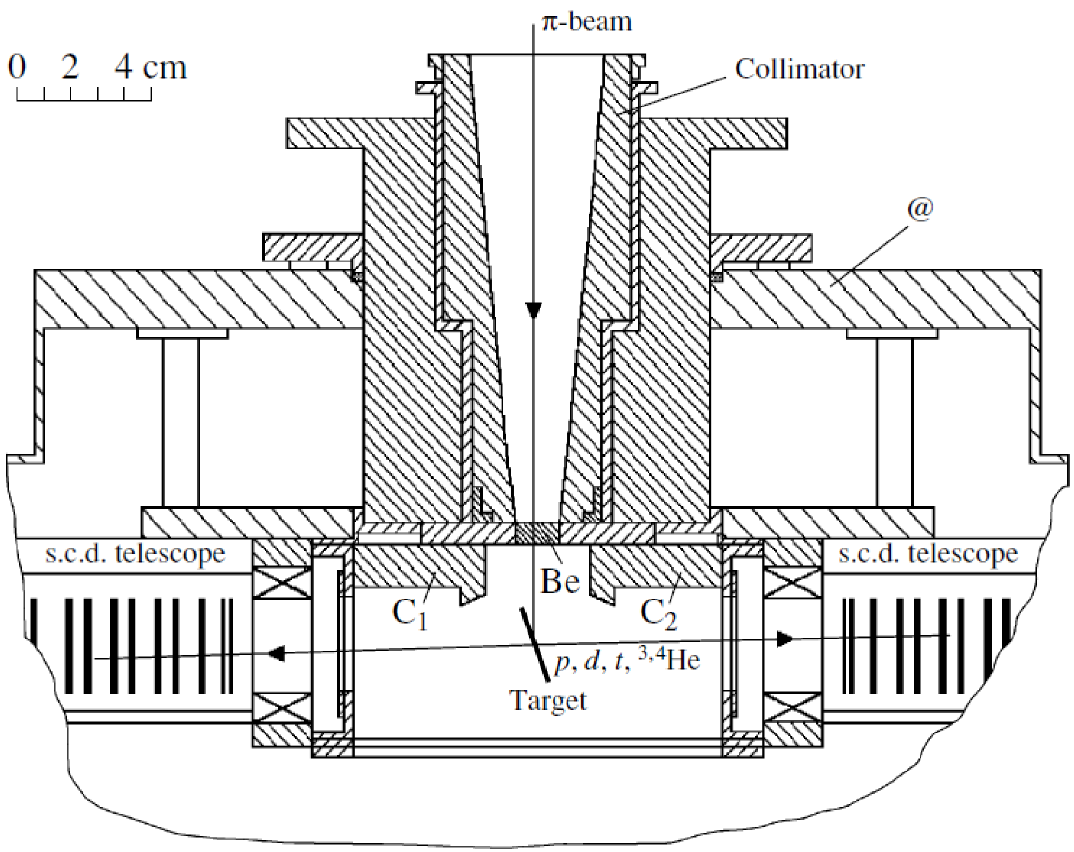
FWHM

ΔE < 0.5 MeV (Z=1)

ΔE < 2.0 MeV (Z=2)

ΔMM < 1 MeV (Z_1=1, Z_2=1)

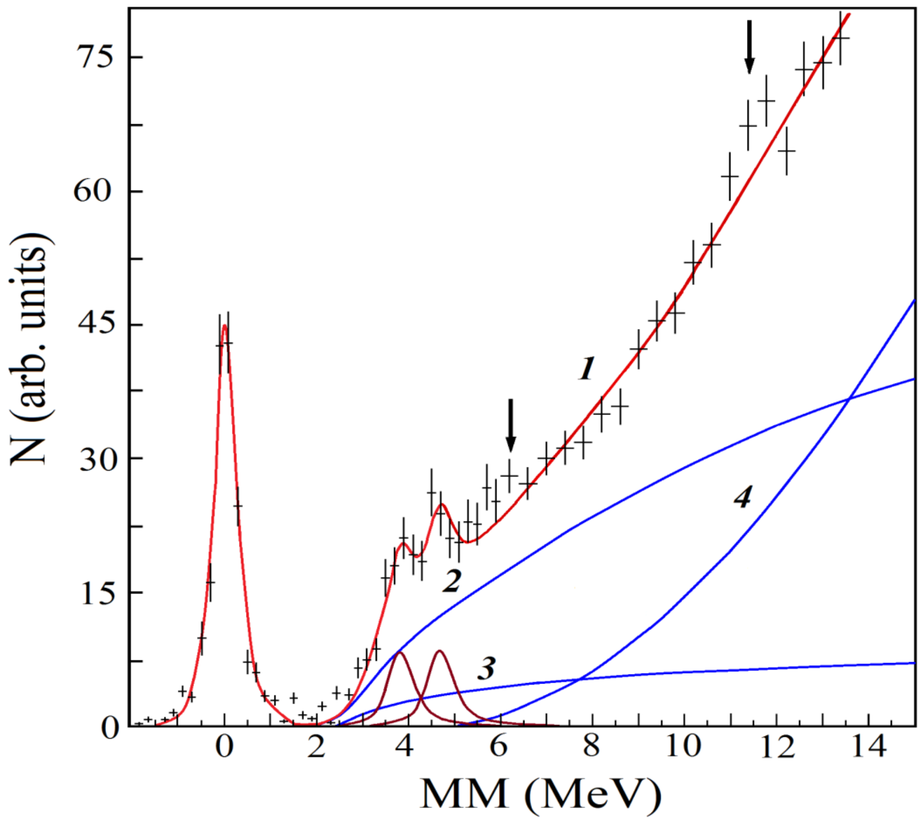
ΔMM < 3 MeV (Z_1=1, Z_2=2)



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

^{8}He production on the ^{9}Be target

$\pi^{-}\ ^{9}Be \rightarrow p\ ^{8}He$



E_x, MeV	Γ, MeV
0.1(1)	0.1(1)
3.9 ± 0.2	≈0.5
4.6 ± 0.3	≈0.5

$E_x \approx 3$ MeV ???

$E_x \approx 6.5$ MeV ???

$E_x \approx 12$ MeV ???

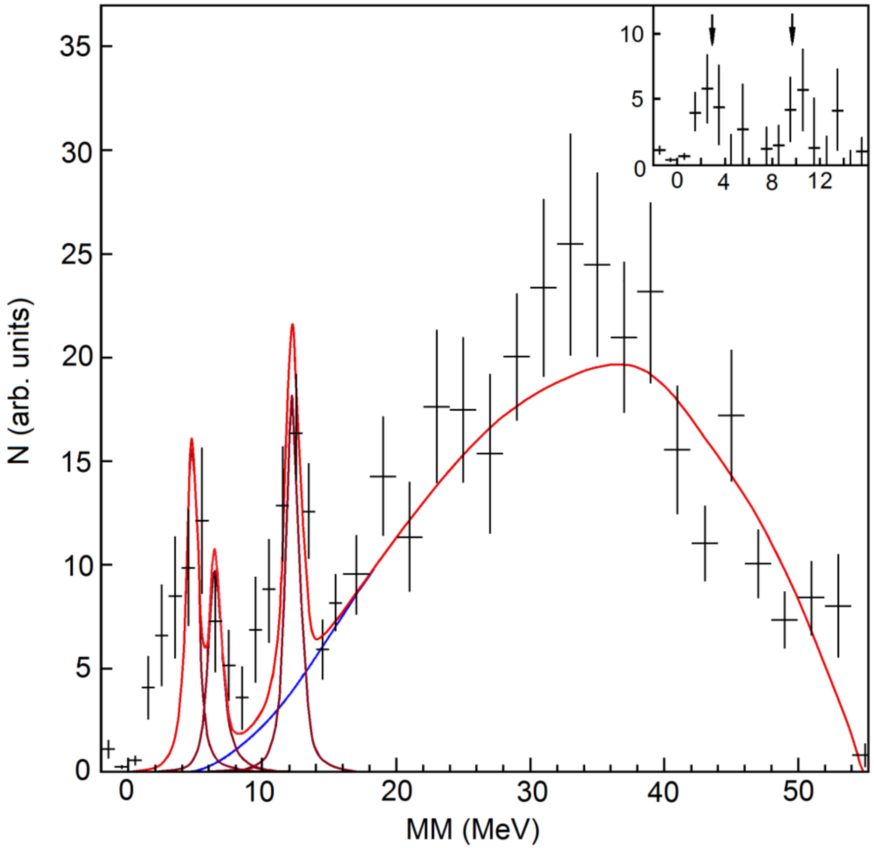
2 - Phase volume $\pi^{-}\ ^{9}Be \rightarrow p + ^{6}He + ^{2}n$

3 - Phase volume $\pi^{-}\ ^{9}Be \rightarrow p + ^{7}He + n$

4 - Phase volume $\pi^{-}\ ^{9}Be \rightarrow p + ^{6}He^{*}(1.797) + 2n$

^{8}He production on the ^{10}B target

$\pi^- \, ^{10}B \rightarrow pp \, ^{8}He$

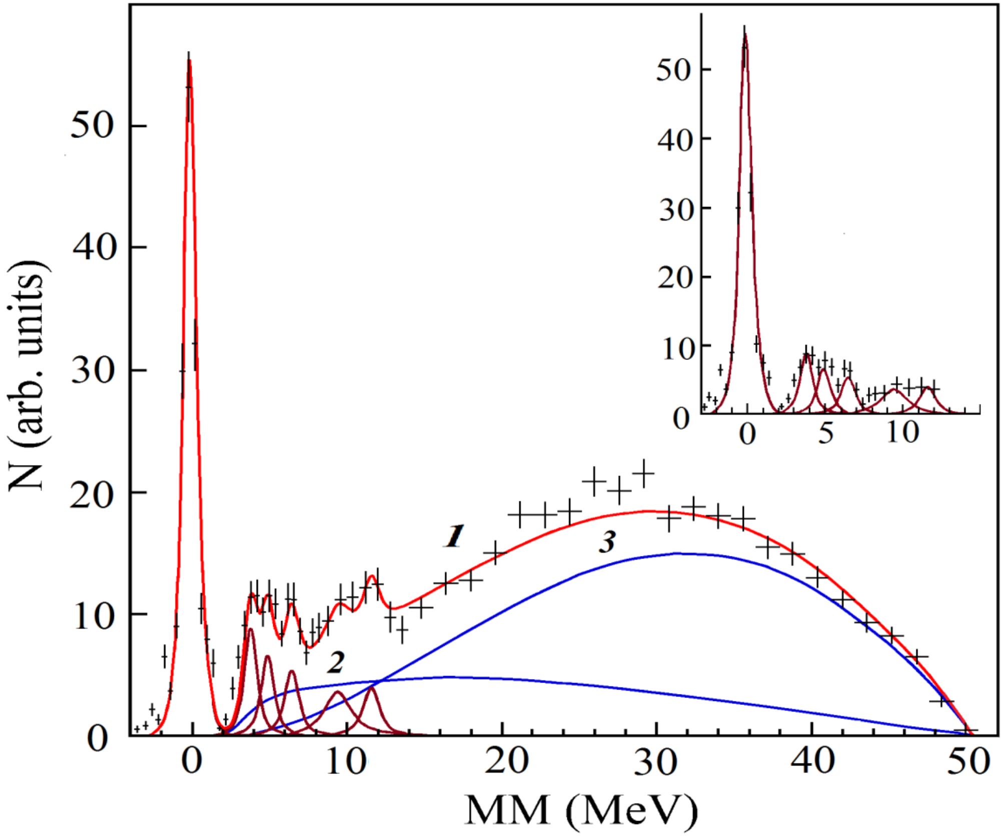


E_x, MeV	Γ, MeV
~3	
≈4.6	<0.6
≈6.4	<0.6
~9.5	
12.2±0.5	0.8±0.3

Phase volume $\pi^- \, ^{10}B \rightarrow pp \, ^{6}He^{*}(1.8)2n$

^{8}He production on the ^{11}B target

$\pi^{-}\ ^{11}B \rightarrow pd\ ^{8}He$



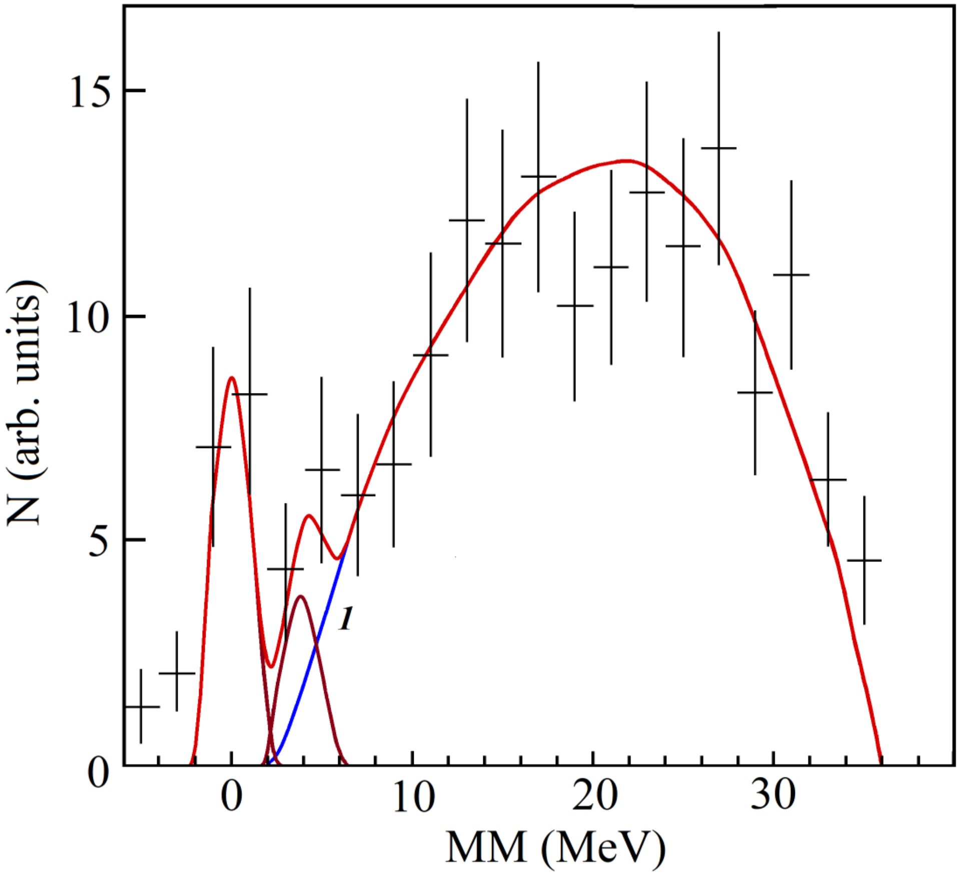
E_x, MeV	Γ, MeV
0.1±0.1	0.1±0.1
3.9	0.5
4.6	0.5
6.4±0.2	0.6±0.3
9.3±0.4	1.7±0.3
11.5±0.3	0.8±0.3

2 - Phase volume $\pi^{-}\ ^{11}B \rightarrow pd\ ^{6}He\ ^{2}n$

3 - Phase volume $\pi^{-}\ ^{11}B \rightarrow pd\ ^{6}He^{*}(1.8)2n$

^{8}He production on the ^{12}C target

$\pi^{-}\ ^{12}C \rightarrow p\ ^{3}He\ ^{8}He$

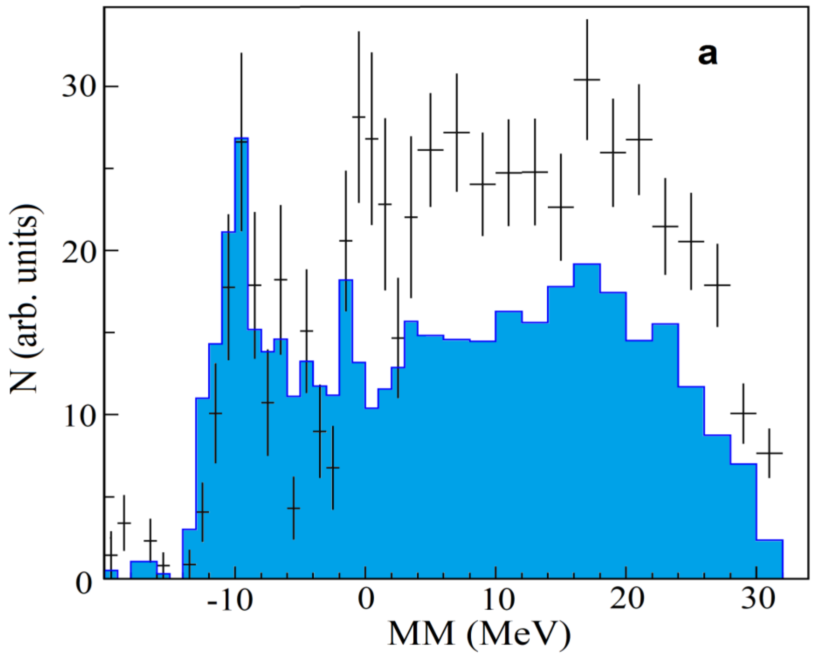


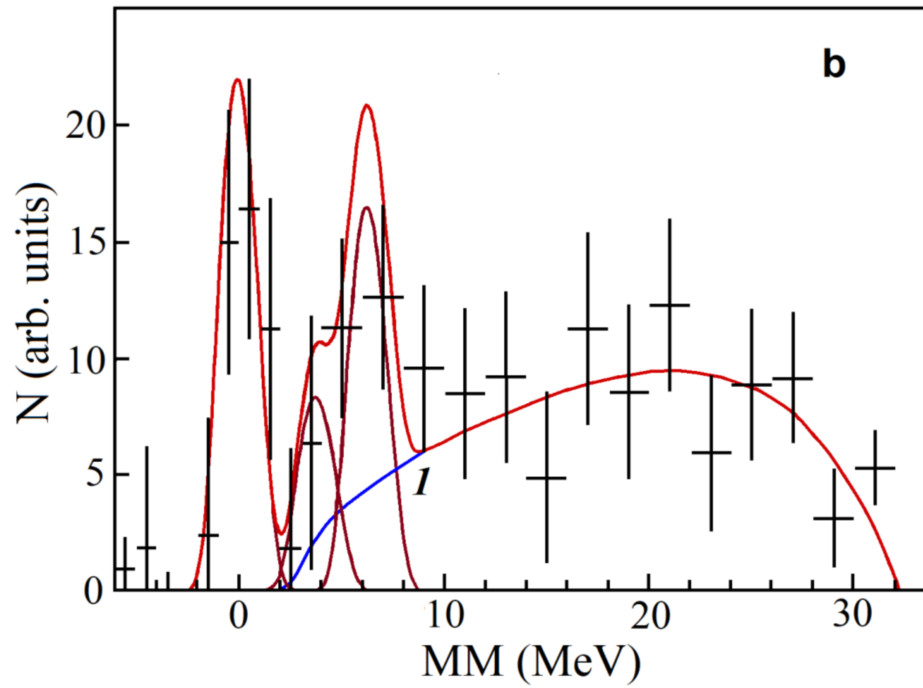
E_x, MeV	Γ, MeV
0.0(1)	<0.2
≈3.9	<1

1- total distribution by phase volumes

^{8}He production on the ^{14}C target

$\pi^{-}\ ^{14}C \rightarrow t\ ^{3}He\ ^{8}He$



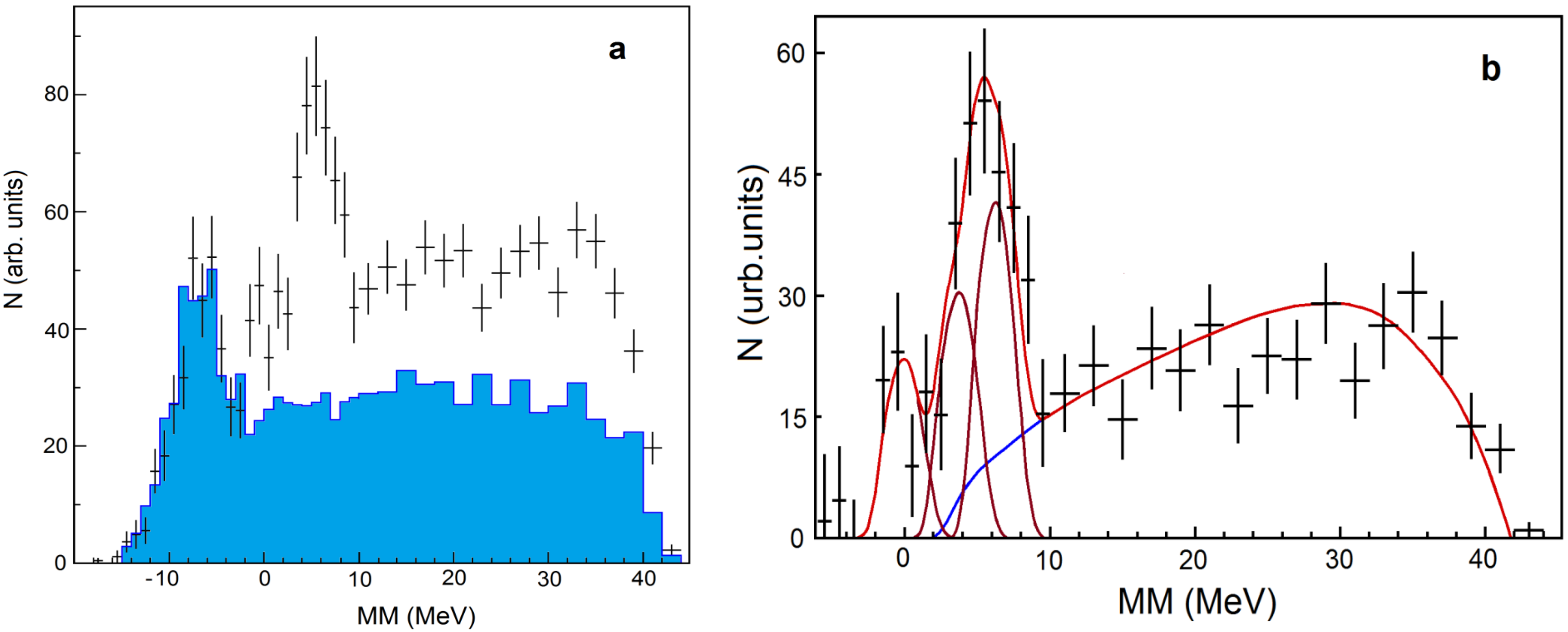


E_x, MeV	Γ, MeV
0.0(1)	<0.2
≈3.9	<1
≈6.4	<1

1- total distribution by phase volumes

^{8}He production on the ^{14}C target

$\pi^{-}\,^{14}C \rightarrow d\,^{4}He\,^{8}He$



E_x, MeV	Γ, MeV
0.0(1)	<0.2
≈3.9	<1
≈6.4	<1

1- total distribution by phase volumes

Excited States of ^{8}He

E_x, MeV	Γ, MeV	J^P	work, reaction
2.6 ÷ 3.6	~0.6	2^+	[1]
≈3	~0.6	(1^-), (2^+)	[3], [4]
≈3 ???			$\pi^-\,{}^{9}$Be → $p\,{}^{8}$He $\pi^-\,{}^{10}$B → pp ^{8}He
3.6 ÷ 3.9	≈0.5	2^+	[2, 3]
3.9 ± 0.2	≈0.5		$\pi^-\,{}^{9}$Be → $p\,{}^{8}$He
≈4.2	1.2	≈(1^-)	[1, 4]
4.6 ± 0.3	≈0.5		$\pi^-\,{}^{9}$Be → $p\,{}^{8}$He $\pi^-\,{}^{10}$B → pp ^{8}He $\pi^-\,{}^{11}$B → pd ^{8}He
5.4(5)	0.5(3)	1^+	[2, 3]
(6.03(10))	0.15(15)		[1]
≈6.4	~0.6		$\pi^-\,{}^{10}$B → pp ^{8}He $\pi^-\,{}^{11}$B → pd ^{8}He $\pi^-\,{}^{14}$C → t^{3}He ^{8}He $\pi^-\,{}^{14}$C → d^{4}He ^{8}He
7.16(4)	0.1(1)	(3^-)	[1, 3]
9.3(4)	1.7(3)		$\pi^-\,{}^{10}$B → pp ^{8}He $\pi^-\,{}^{11}$B → pd ^{8}He
12.2(3)	0.8(3)		$\pi^-\,{}^{10}$B → pp ^{8}He $\pi^-\,{}^{11}$B → pd ^{8}He

Conclusion

•The level structure of the heavy helium isotope ^{8}He was experimentally determined in 6 channels of the reaction of the stopped pion absorption by ^{9}Be, $^{10.11}$B, and $^{12.14}$C nuclei.

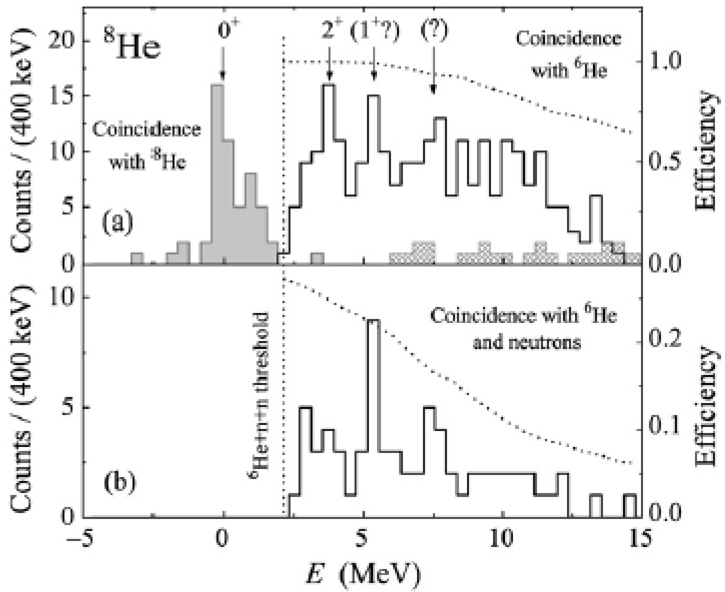
•Data for low-lying states coincide with the results of other authors.

•An excess of events is observed near the decay threshold, which may be related to the soft dipole resonance predicted by the Dubna group.

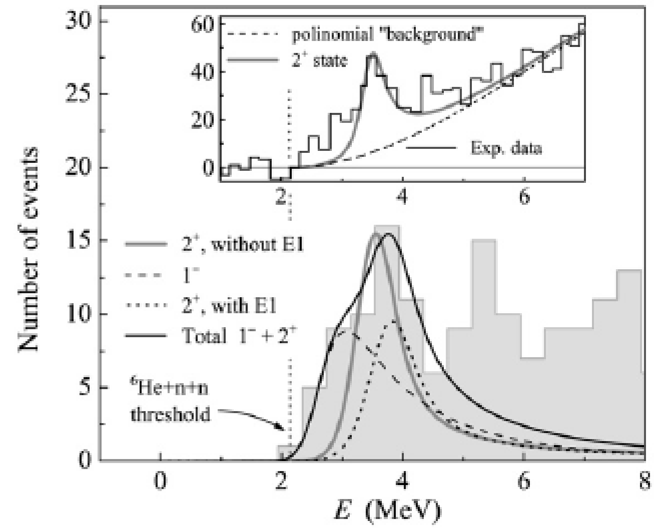
•For the first time, highly excited levels were observed at $E_x \approx$ 6.4, 9.3 and 12.2 MeV.

Thank you

for your attention!



^{8}He
0$^+$
2$^+$ (1$^+$?)
(?)
Coincidence with ^{6}He
Coincidence with ^{8}He
(a)
(b)
Coincidence with ^{6}He and neutrons
^{6}He+n+n threshold
Counts / (400 keV)
Efficiency
E (MeV)



polinomial "background"
2$^+$ state
Exp. data
2$^+$, without E1
1$^-$
2$^+$, with E1
Total 1$^-$ + 2$^+$
^{6}He+n+n threshold
Number of events
E (MeV)