The 3rd International Conference on Particle Physics and Astrophysics

Spectroscopy of Helium Isotope 6He

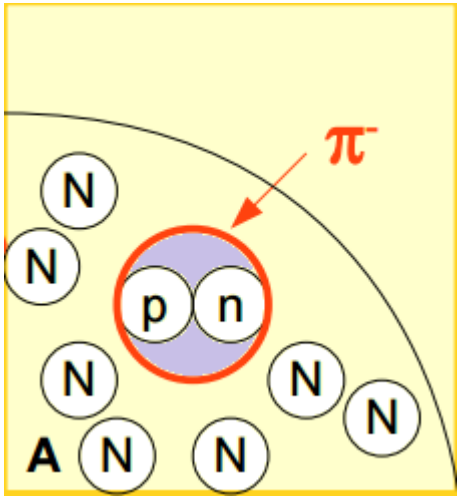
B.A. Chernyshev

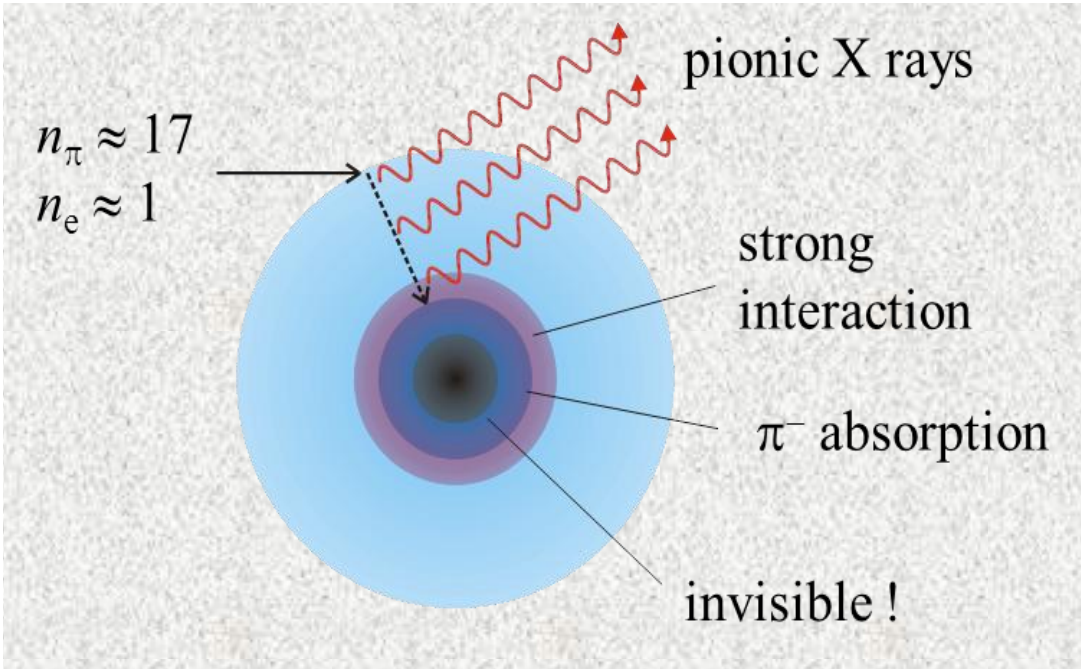
National Research Nuclear University "MEPhI"

Moscow, 2017

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

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





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

$\pi^- + pp \rightarrow pn$

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

$\downarrow$

$n+d \rightarrow t$

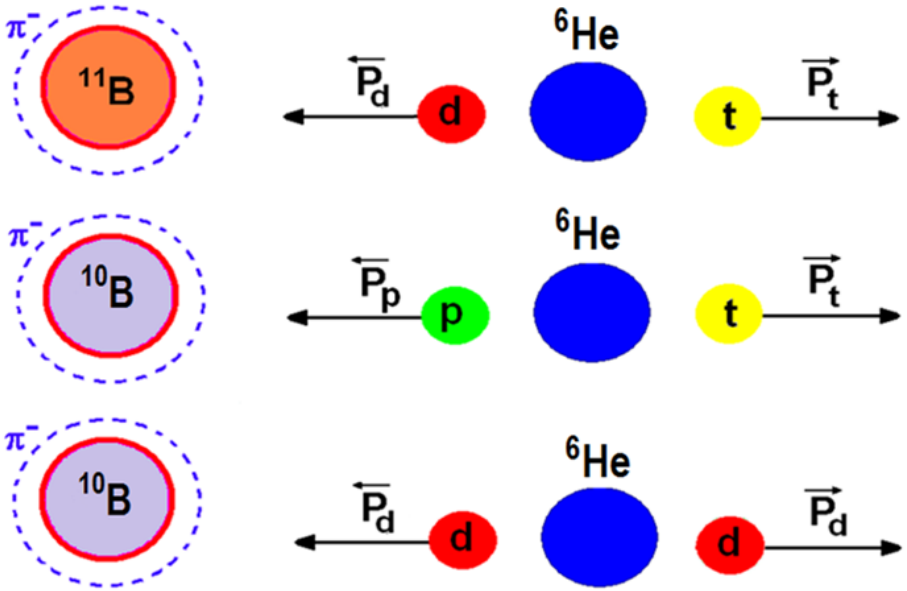
Cluster absorption

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

Secondary pick-up

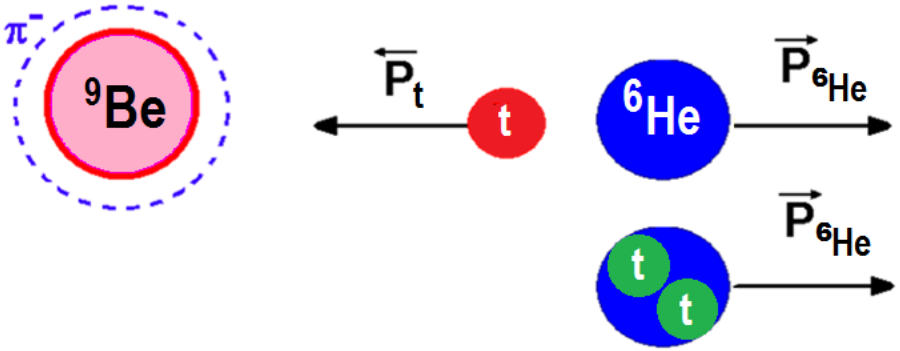
Stopped pion absorption by nuclei – Tool for production of neutron-rich states

Three-body channels

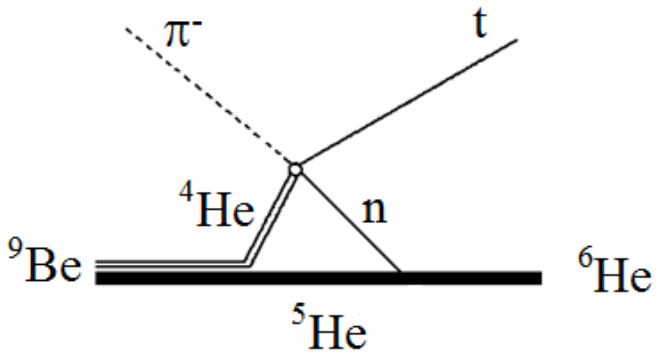


P_R ~ 100 MeV/c

Two-body channels



P_R ~ 500 ÷ 700 MeV/c



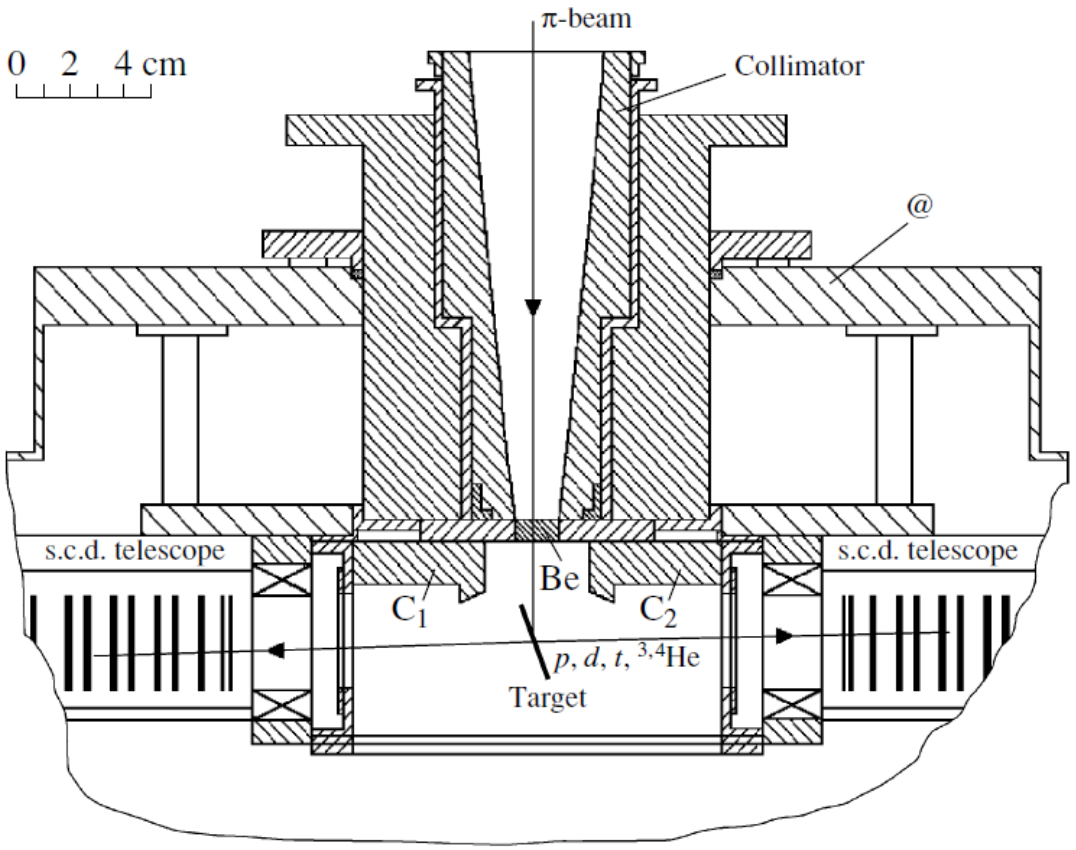
Layout of spectrometer (LAMPF)

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,	~ 6·10^4	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)

ΔMM < 1 MeV (Z=1)

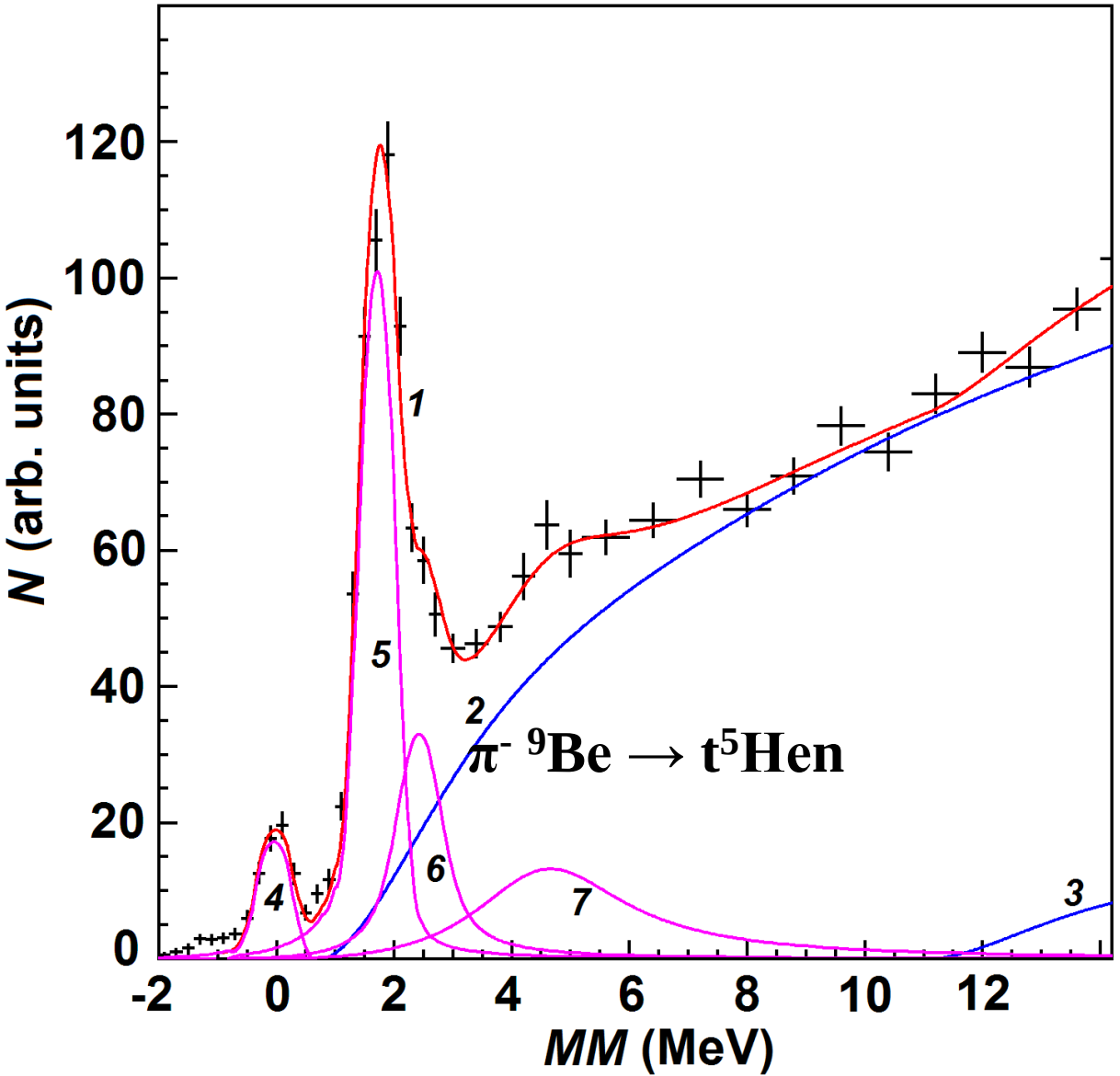


•*Gornov M. G. et al.* // Nucl. Inst. and Meth. in Phys. Res. A 2000. V. 446. P. 461.

^{6}He production on the ^{9}Be

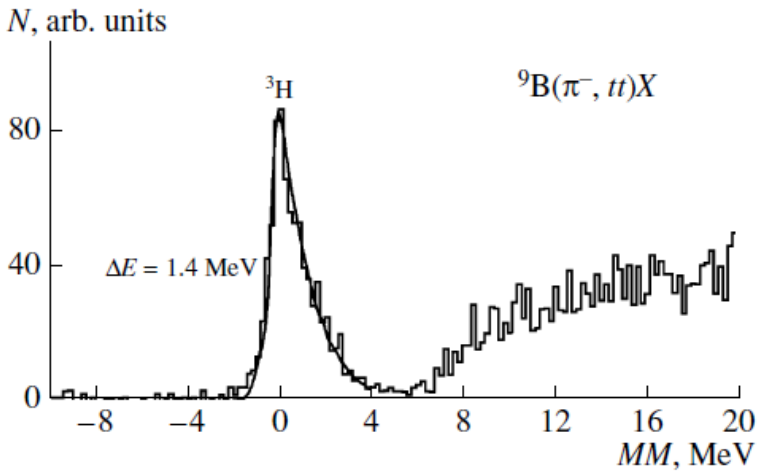
π^{-} ^{9}Be → tX

	E_x, MeV	Γ, MeV
4	0 (g.s.)	0
5	1.797(25)	0.11(2)
6	2.5(2)	0.5(2)
7	4.8(2)	2.9(2)

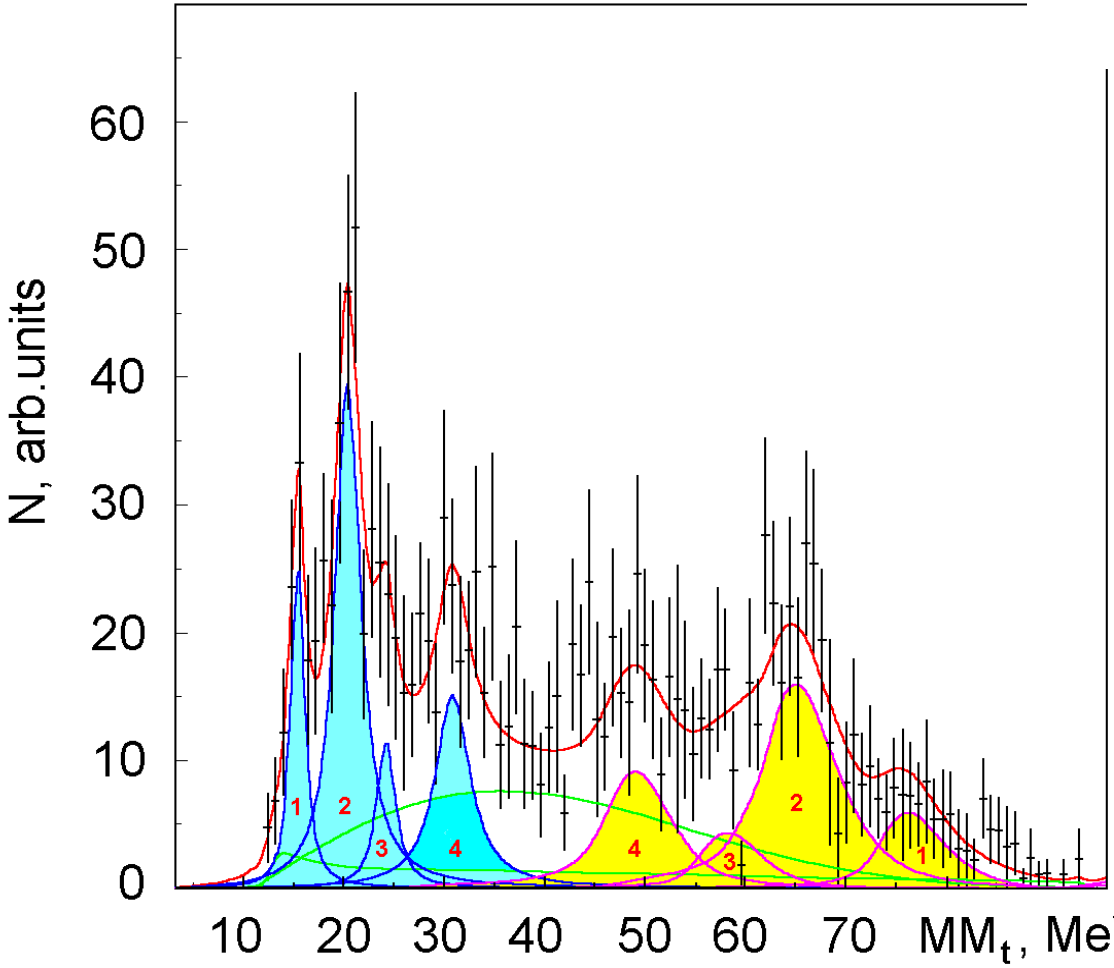


$^6He^*$ – t+t resonance

E_{thr} = 12.305 MeV



π^- ^{9}Be → tt(t)



π^- ^{9}Be → t $^6He^*$

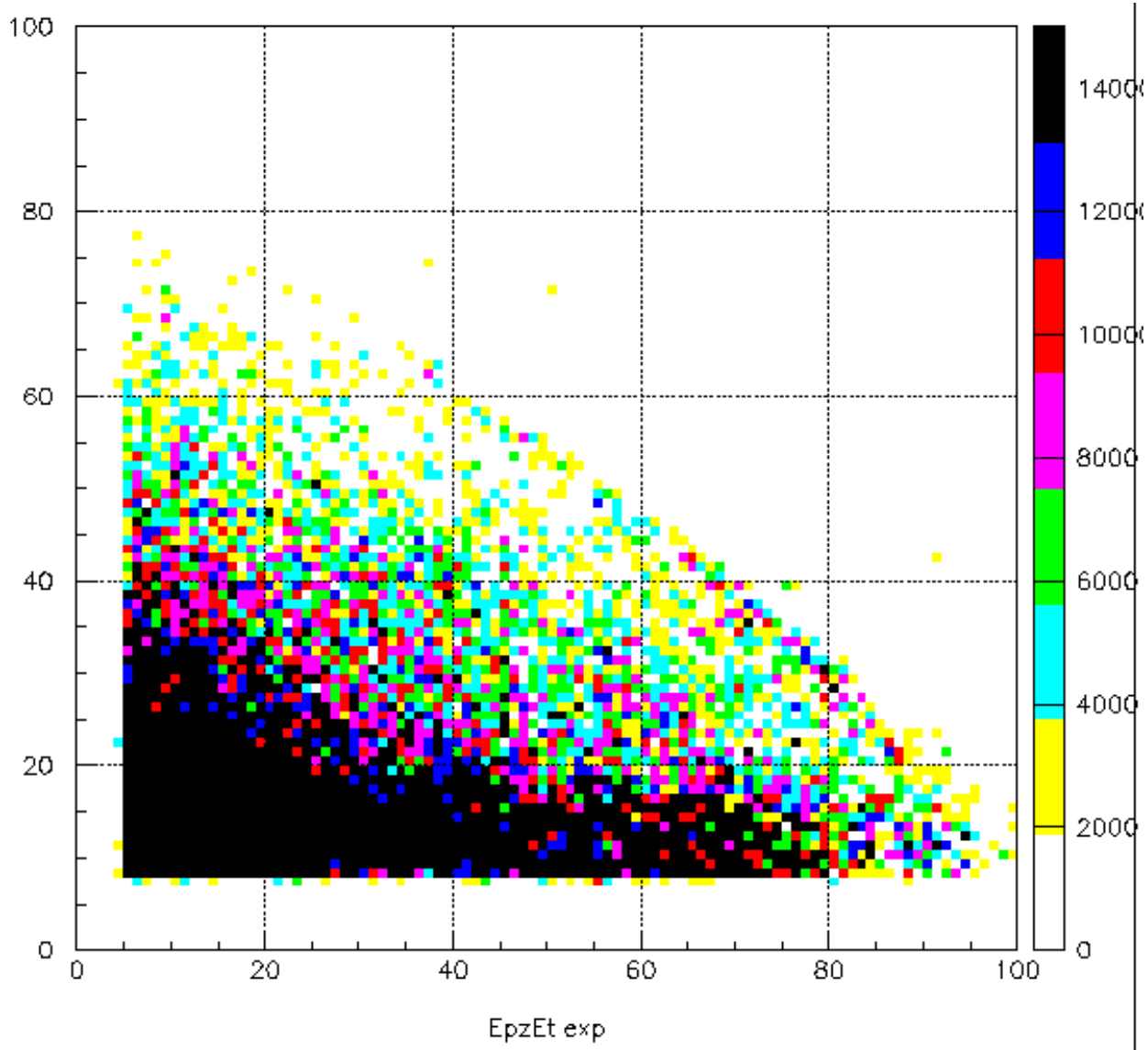
$^6He^*$ → tt

	E_x, MeV	Γ, MeV
1	15.6(3)	1.3(8)
2	20.6(1)	2.9(1.5)
3	24.4(9)	2.0(8)
4	31.0(7)	4.0(9)

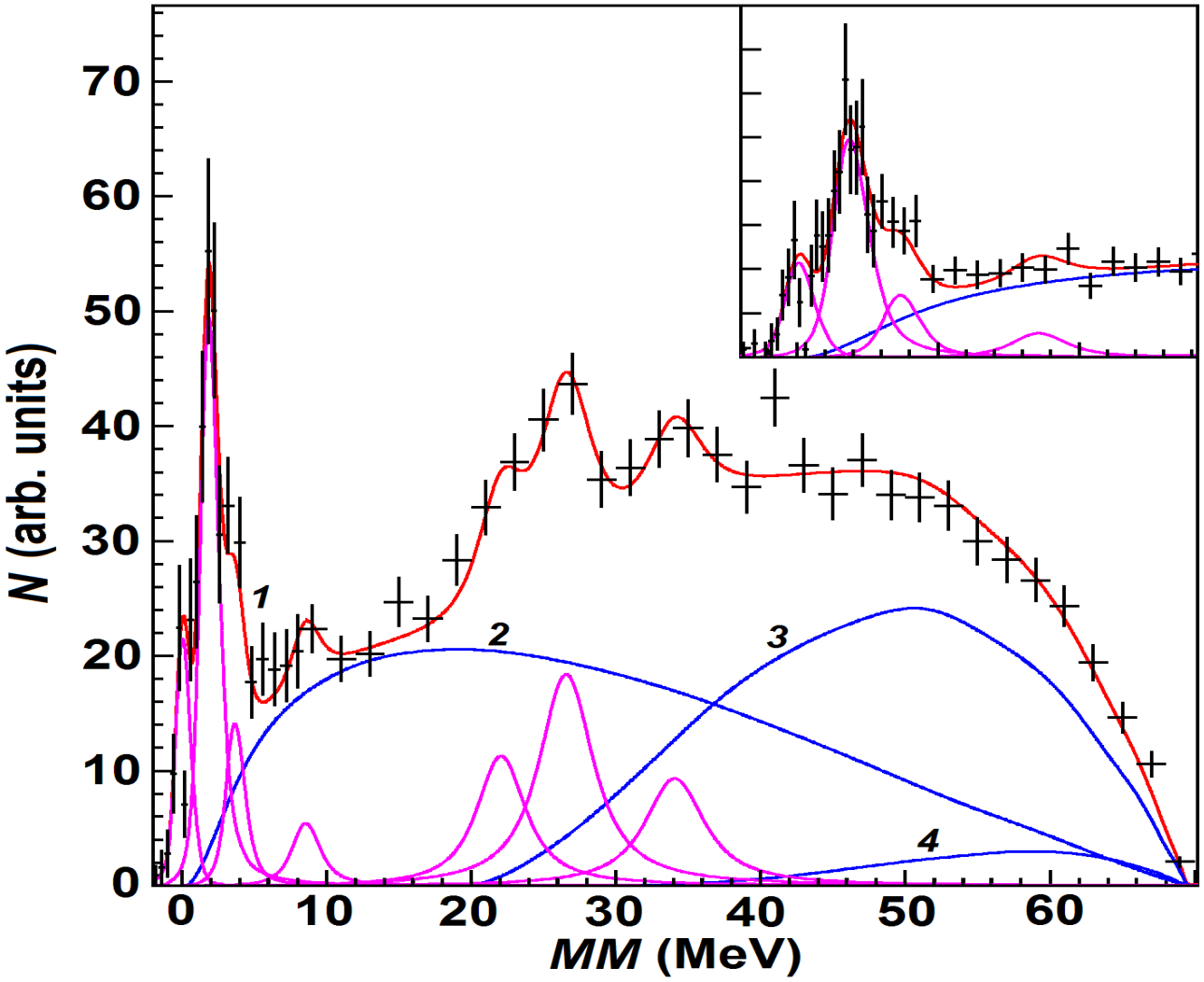
E_{freeN} = 29.269 MeV

^{6}He production on the boron isotope

π^{-} ^{10}B → pt(X)

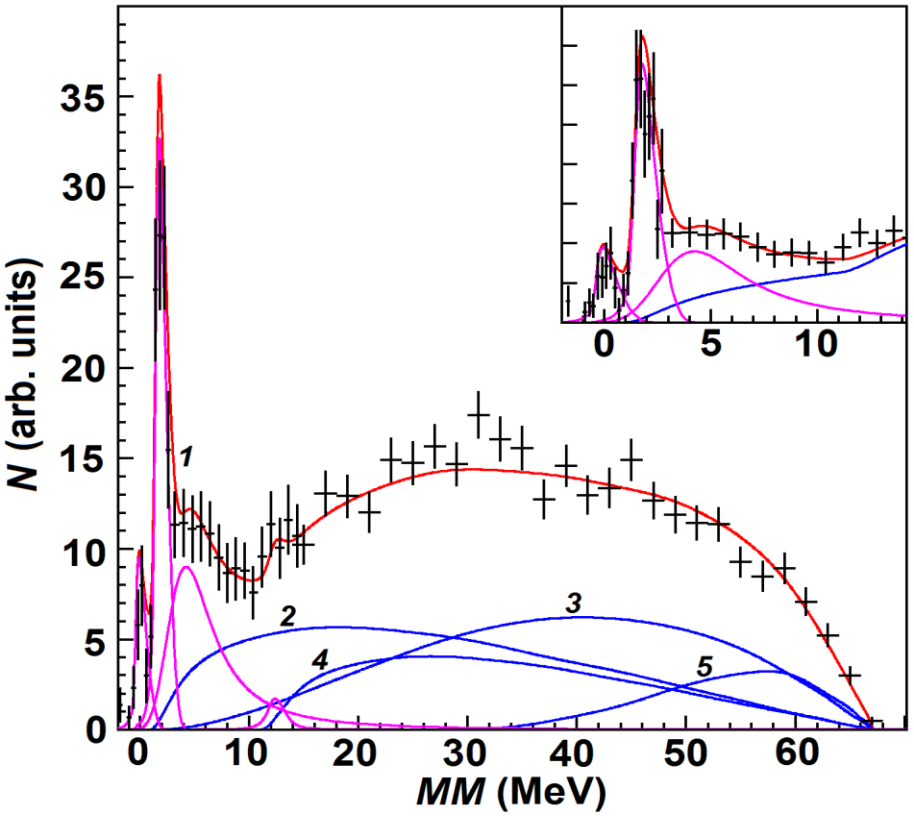


π^- ^{10}B → pt(X)



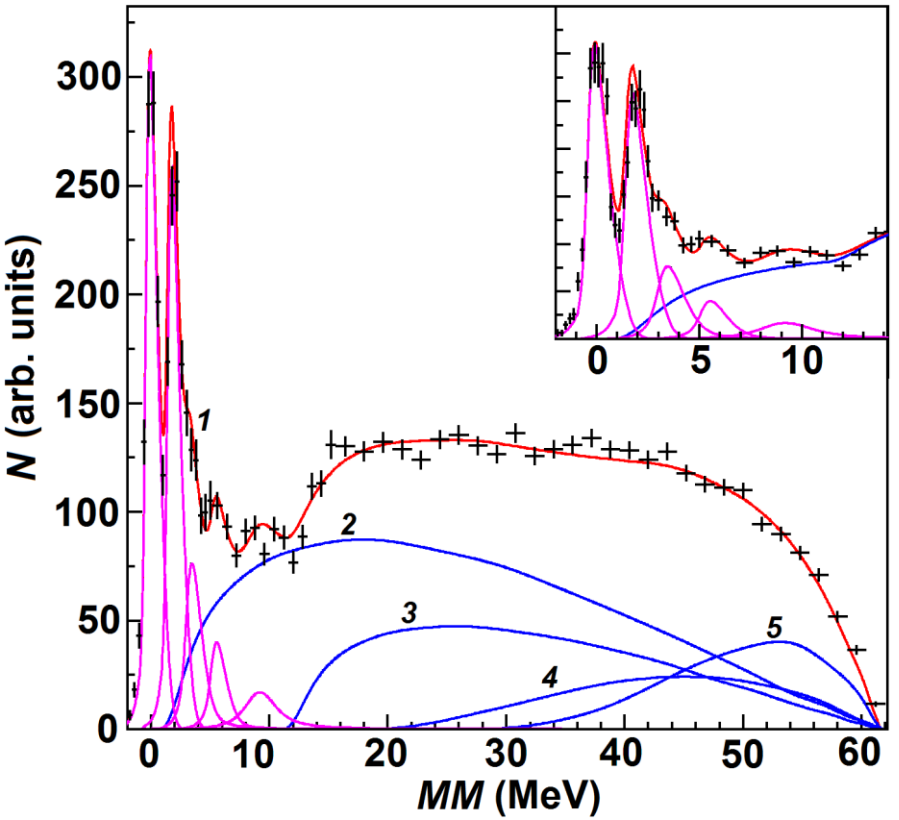
	E_x, MeV	Γ, MeV
1	0 (g.s.)	0
2	1.8(1)	0.4(3)
3	3.6(3)	0.5(4)
4	8.5(5)	1.5(5)
5	≈22.	≈3.5
6	≈26	≈4
7	≈34	≈4.5

$\pi^- {}^{10}B \rightarrow dd(X)$



	E_x, MeV	Γ, MeV
1	0 (g.s.)	0
2	1.9(4)	0.1(1)
3	3.8(3)	0.5(4)

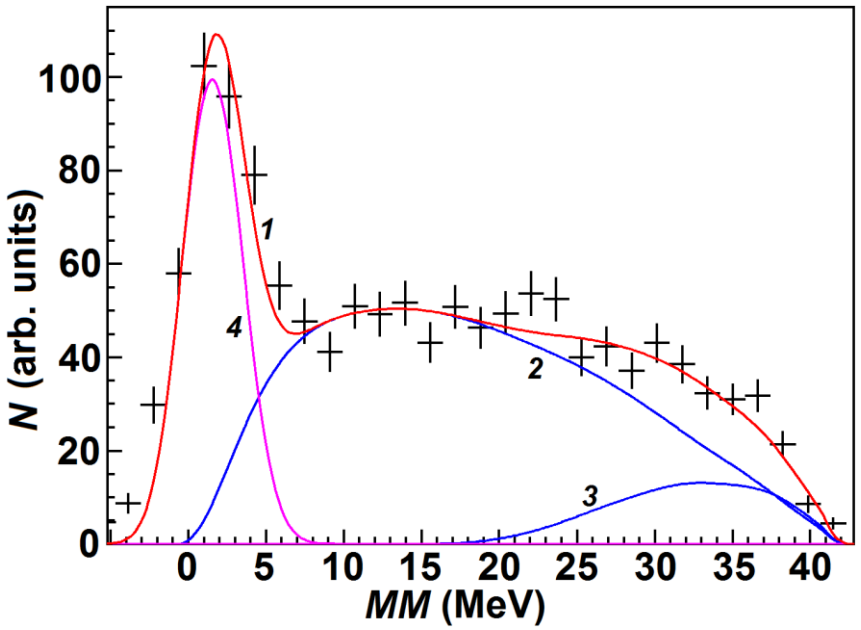
$\pi^- {}^{11}B \rightarrow dt(X)$



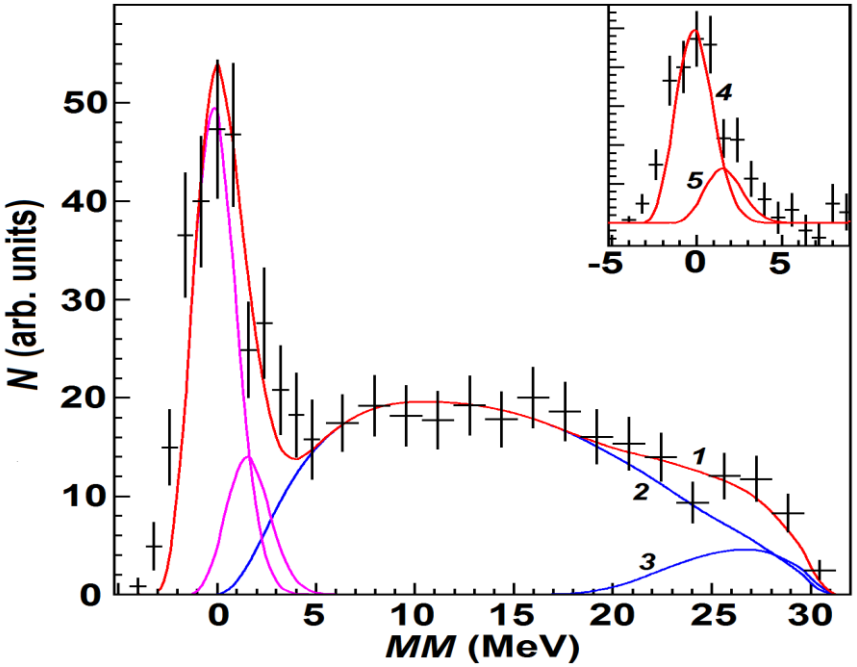
	E_x, MeV	Γ, MeV
1	0 (g.s.)	0
2	1.9(4)	0.1(1)
3	3.5(3)	0.5(4)
4	≈9.1	≈2.5

^{6}He production on the ^{12}C

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

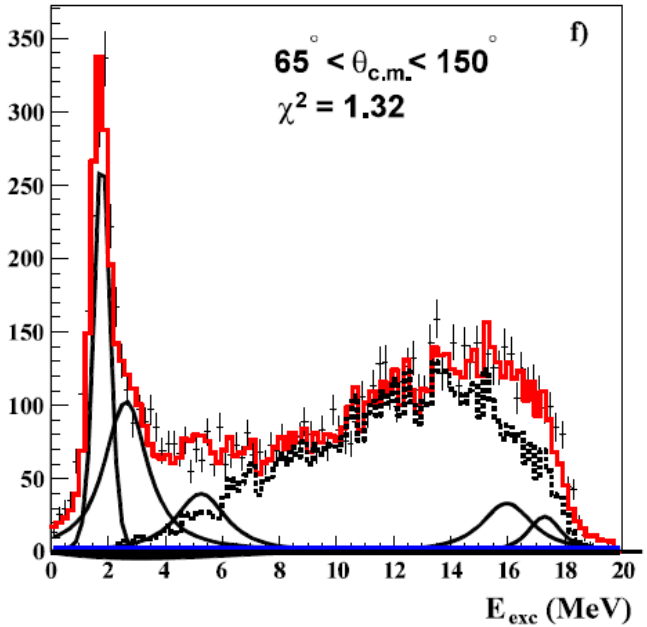


$\pi^{-}\ ^{12}C \rightarrow t^{3}HeX$

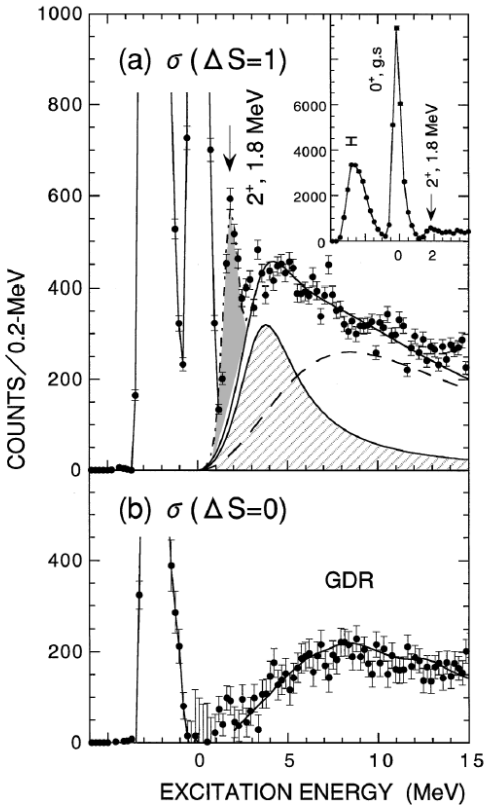


^{6}He – Excited Energy ~ 4 MeV

E_x, MeV	Γ, MeV	Our data	Work
2.5(2)	0.5(2)	^{9}Be(π^-,t)X	
2.6(3)	1.6(4)		[4]
3.5(3)	0.5(4)	^{11}B(π^-,dt)X	
3.6(3)	0.5(4)	^{10}B(π^-,pt)X	
3.8(3)	0.5(4)	^{10}B(π^-,dd)X	
3.6(2)	0.5(3)	medium	
4 (1)	4(1)		[11]
4.8(2)	2.9(2)	^{9}Be(π^-,t)X	
5.5(3)[a]	~3[a]		[3,4]
5.6(3)	12.1(1.1)		[1]



^{6}Li(^{7}Li,^{7}Be)^{6}He E = 455 MeV



[11] *Nakayama S. et al.* // Phys. Rev. Lett. 2000. V. 85, 262.

[4] *Mougeot X. et al.* // Phys. Lett. B. 2012. V.718, № 2. P.441.

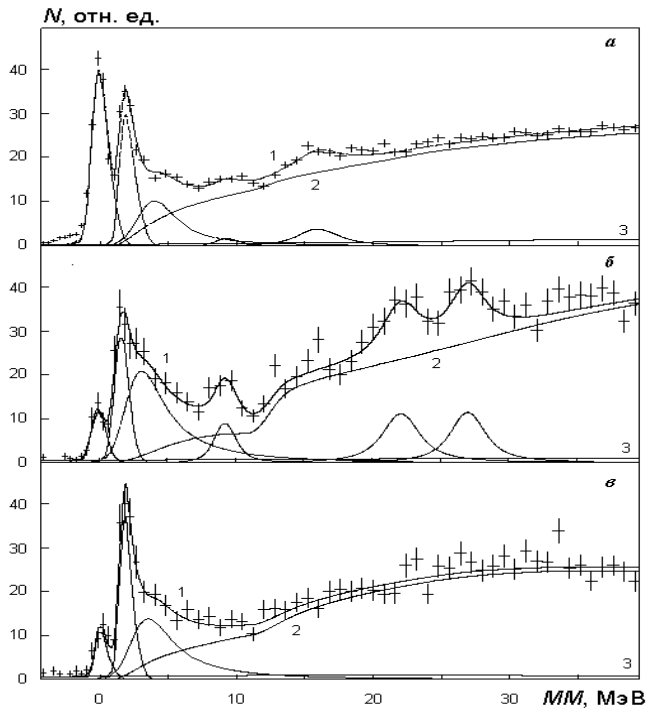
p(^{8}He,t)X E = 15.4*A* MeV

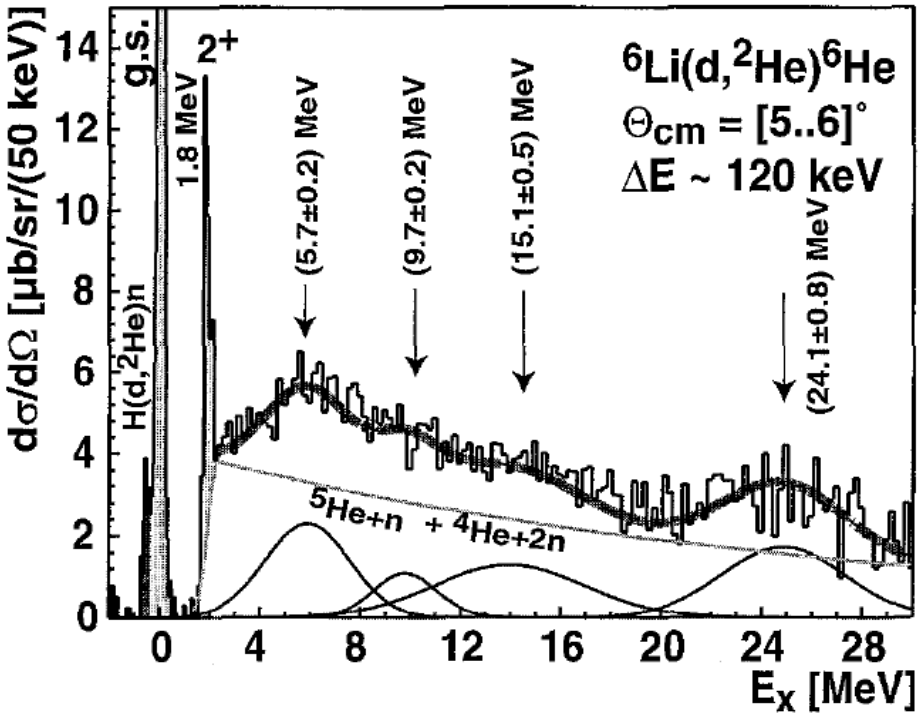
^{6}He – Excited Energy ~ 9 MeV

E_x, MeV	Γ, MeV	Our data	Work
≈9.1	≈2.5	^{11}B(π^-,dt)X	
8.5(5)	1.5(5)	^{10}B(π^-,pt)X	
8.8(5)	2.0(5)	medium	
9.7(2)	~3		[3]

[3] *Frekers D.* // Nucl. Phys. A 2004. V.731. P. 76.

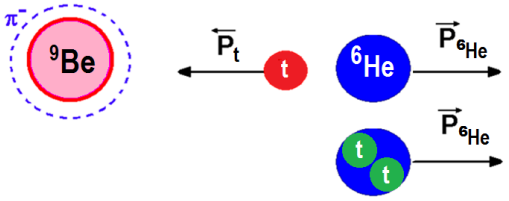
^{6}Li(d,^{2}He)^{6}He E = 171 MeV





^{6}He – Excited energy exceeding the decay threshold

^{6}He → t+t (12.3 MeV)



^{6}He → d+^{4}H (≈ 20 MeV)

^{6}He → p+^{5}H (≈ 25 MeV)

E_r (^{6}H) = 6.6 MeV) E_r (IAS) ≈ 4.5 MeV

E_x, MeV	Γ, MeV	Our data	Work
14.0(4) 14	0.7(3)		[6] [10]
14.6(7)	7.4(1.0)		[1]
15.1(5)	~7		[3]
15.5(5)	4(2)		[1]
15.6(3)	1.3(8)	^{9}Be(π⁻,tt)t	
16.1(4)	0.8(4)		[6]
18.3(2)	1.1(3)		[6]
20.6(1)	2.9(1.5)	^{9}Be(π⁻,tt)t	
≈22	≈3.5	^{10}B(π⁻,pt)X	
≈24[a]	≈10[a]		[1,3,10]
24.4(9)	2.0(8)	^{9}Be(π⁻,tt)t	
≈26	≈4	^{10}B(π⁻,pt)X	
31.0(7)	4.0(9)	^{9}Be(π⁻,tt)t	
32.0	≤ 2		[7]
≈34.0	≈4.5	^{10}B(π⁻,pt)X	

[10] С. Б. Сакута и др., ЯФ 65, 1819 (2002).

^{7}Li(^{6}Li, ^{7}Be)^{6}He

[1] *Tilley D. R. et al.* // Nucl. Phys. A. 2002. V. 708. № 1. P. 3.

[3] *Frekers D.* // Nucl. Phys. A 2004. V.731. № 1. P. 76

[6] *Povoroznyk O. M. et al.* // Phys. Rev. C. 2012. V.85, № 6. P.064330.

^{3}H(α,tt)^{1}H E_α = 67.2 МэВ

[7] *Franke R. et al.* // Nucl. Phys. A. 1985. V. 433, № 3. P.351.

^{7}Li(^{3}He, p^{3}He)^{6}He E = 120 МэВ

Conclusion

Candidate for IAS of superheavy hydrogen isotope ^{6}H

E_r (^{6}He) = 26.0 MeV

E_r (^{6}H) ≈ 4.5 MeV

We observed few states lying above the threshold of decay into free nucleons

Thank you
for your attention!

The 3rd International Conference on Particle Physics and Astrophysics

Spectroscopy of Helium Isotope 6He

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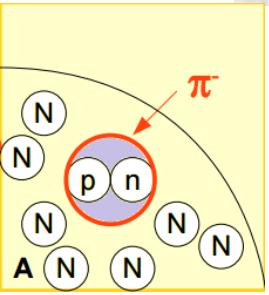
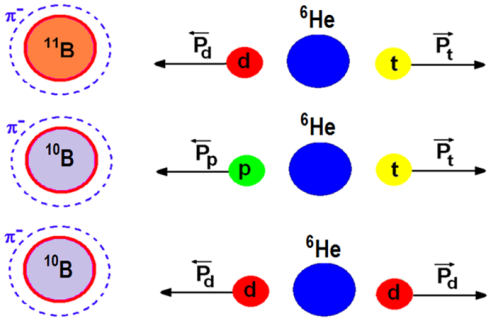
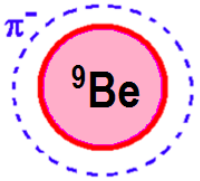
Stopped pion absorption by nuclei –Tool for production of neutron-rich states

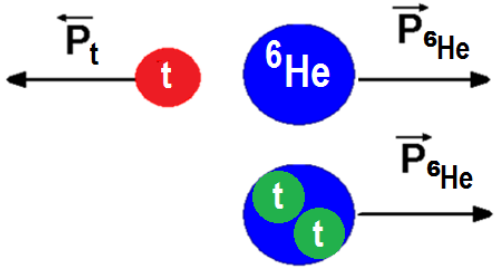
$$\pi^- + {}^{9}\mathrm{Be},\ {}^{10,11}\mathrm{B} \rightarrow \text{exotic nuclei} + X$$

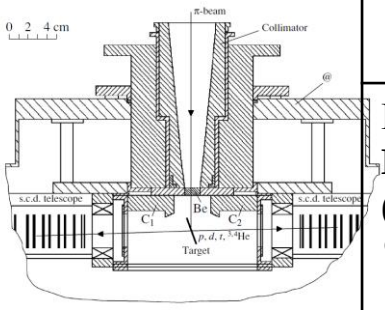


$$\pi^- + pn\ (T=0,\ S=1,\ l_{pn}=0) \rightarrow nn$$









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,	~ 6·10^4	2 Si(Au) -T=100, 450μm 14 Si(Li) -T=3 mm, Wd≈0.1mm S=8 mm^2 Ω=55÷15 mster	$E_p \approx 3.5$, $E_d \approx 4$, $E_t \approx 4.5$, $E_{He} \approx 15$.

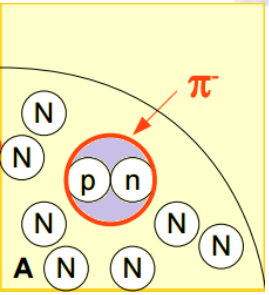
Спектроскопия изотопа гелия 6He

Б.А. Чернышев

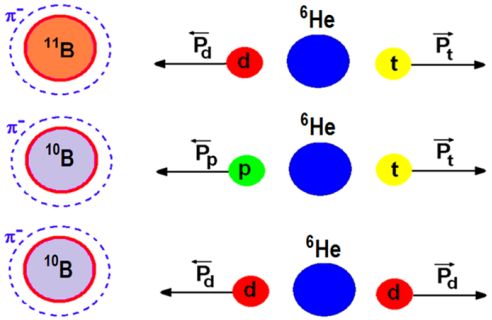
Национальный исследовательский Ядерный Университет "МИФИ"

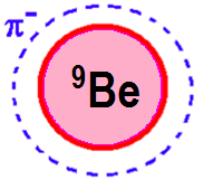
Понлощение остановившихся пионов ядрами–Инструмент для рождения нейтронно-избыточных состояний

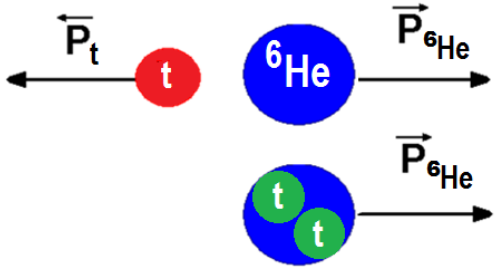
$$\pi^- + {}^{9}\mathrm{Be},\ {}^{10,11}\mathrm{B} \rightarrow \text{exotic nuclei} + X$$

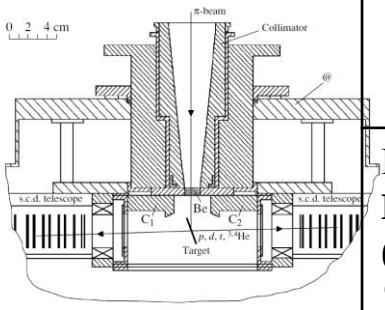


$$\pi^- + pn\ (T=0,\ S=1,\ l_{pn}=0) \rightarrow nn$$

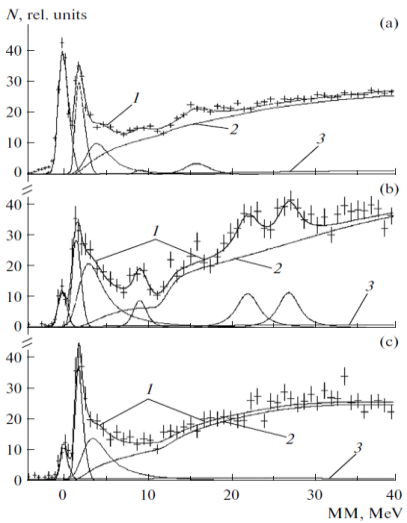


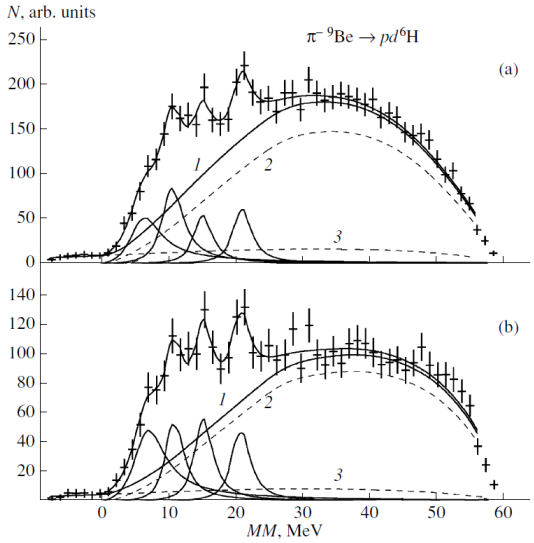


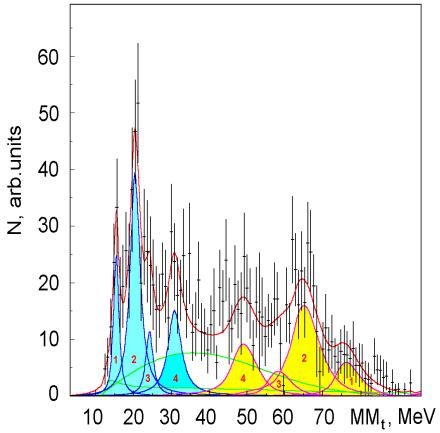




Пучок	Мишень	Размеры и примеси	Скорость ост., 1/s	ППД-теелскопы	Пороги (MeV)
Eπ= 30 MeV (Δp/p=±1 %)	^{9}Be ^{10,11}B ^{12,14}C	Толщина – 25 mg/sm^2, (135μm), Диаметр – 26 mm,	~ 6·10^4	2 Si(Au) -T=100, 450μm 14 Si(Li) -T=3 mm, Wd≈0.1mm S=8 mm^2	$E_p \approx 3.5$, $E_d \approx 4$, $E_t \approx 4.5$, $E_{He} \approx 15$.





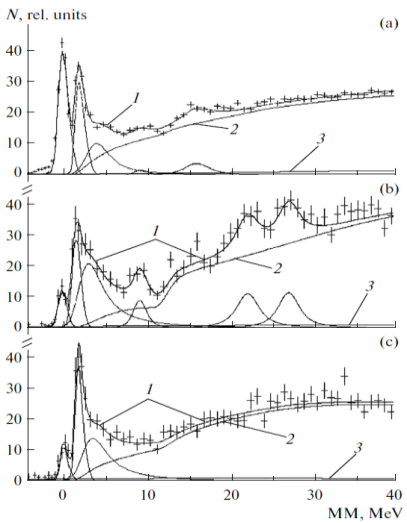


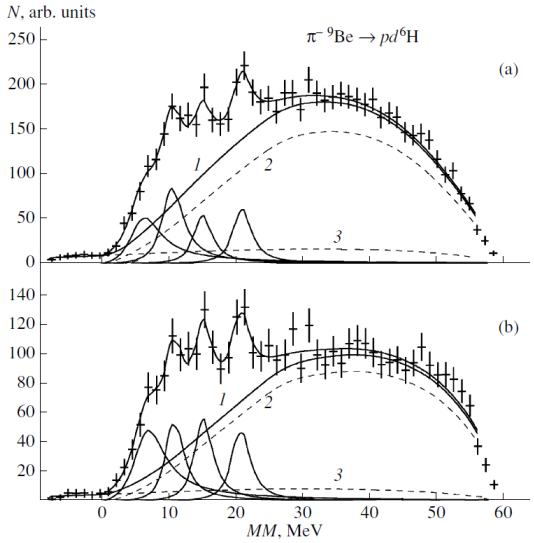
E_x, MeV	Γ, MeV	Our	Work
g.s.	-	1), 2), 3)	[1]
1.797(25)	0.113(20)	1), 2), 3)	[1]
2.6(3)	1.6(4)		[4]
3.5(2)[a]	3.1(4)[a]	1), 2), 3)	
4(1)	4(1)		[11]
5.5(3)[a]	~3[a]		[3,4]
5.6(3)	12.1(1.1)		[1]
9.3(2)[a]	1.0(4)[a]	1), 2)	
9.7(2)	~3		[3]
14.0(4)	0.7(3)		[6]
14.6(7)	7.4(1.0)		[1]
15.1(5)	~7		[3]
15.5(5)	4(2)		[1]
15.8(6)	1.1(0.6)		[8]
15.9(5)	3.2(0.7)	1)	
16.1(4)	0.8(4)		[6]
18.3(2)	1.1(3)		[6]
20.9(3)	3.2(0.6)		[8]
22.1(1.0)	2.7(1.4)	2)	
≈24[a]	≈10[a]		[1,3]
27.0(8)	2.5(1.1)	2)	
31.1(1.0)	6.9(2.3)		[8]
32.0	≤ 2		[7]
35.7	≤ 2		[7]

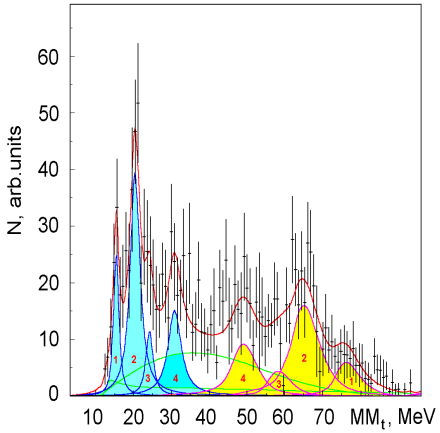
Candidates for IAS of superheavy hydrogen isotopes

E_r (^{6}He) = 27.0(8) MeV

E_r (^{6}H) ≈ 5.5 MeV







E_x, MeV	Γ, MeV	Our	Work
g.s.	-	1), 2), 3)	[1]
1.797(25)	0.113(20)	1), 2), 3)	[1]
2.6(3)	1.6(4)		[4]
3.5(2)[a]	3.1(4)[a]	1), 2), 3)	
4(1)	4(1)		[11]
5.5(3)[a]	~3[a]		[3,4]
5.6(3)	12.1(1.1)		[1]
9.3(2)[a]	1.0(4)[a]	1), 2)	
9.7(2)	~3		[3]
14.0(4)	0.7(3)		[6]
14.6(7)	7.4(1.0)		[1]
15.1(5)	~7		[3]
15.5(5)	4(2)		[1]
15.8(6)	1.1(0.6)		[8]
15.9(5)	3.2(0.7)	1)	
16.1(4)	0.8(4)		[6]
18.3(2)	1.1(3)		[6]
20.9(3)	3.2(0.6)		[8]
22.1(1.0)	2.7(1.4)	2)	
≈24[a]	≈10[a]		[1,3]
27.0(8)	2.5(1.1)	2)	
31.1(1.0)	6.9(2.3)		[8]
32.0	≤ 2		[7]
35.7	≤ 2		[7]

Кандидаты на ИАС сверхтяжелого изотопа водорода 6H

E_r (^{6}He) = 27.0(8) MeV

E_r (^{6}H) ≈ 5.5 MeV