Studies of the reference and satellite nuclear reactions in search for light neutron-rich nuclear systems

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for ACCULINNA-2 collaboration

Breakthrough results on ^{6,7}H studies

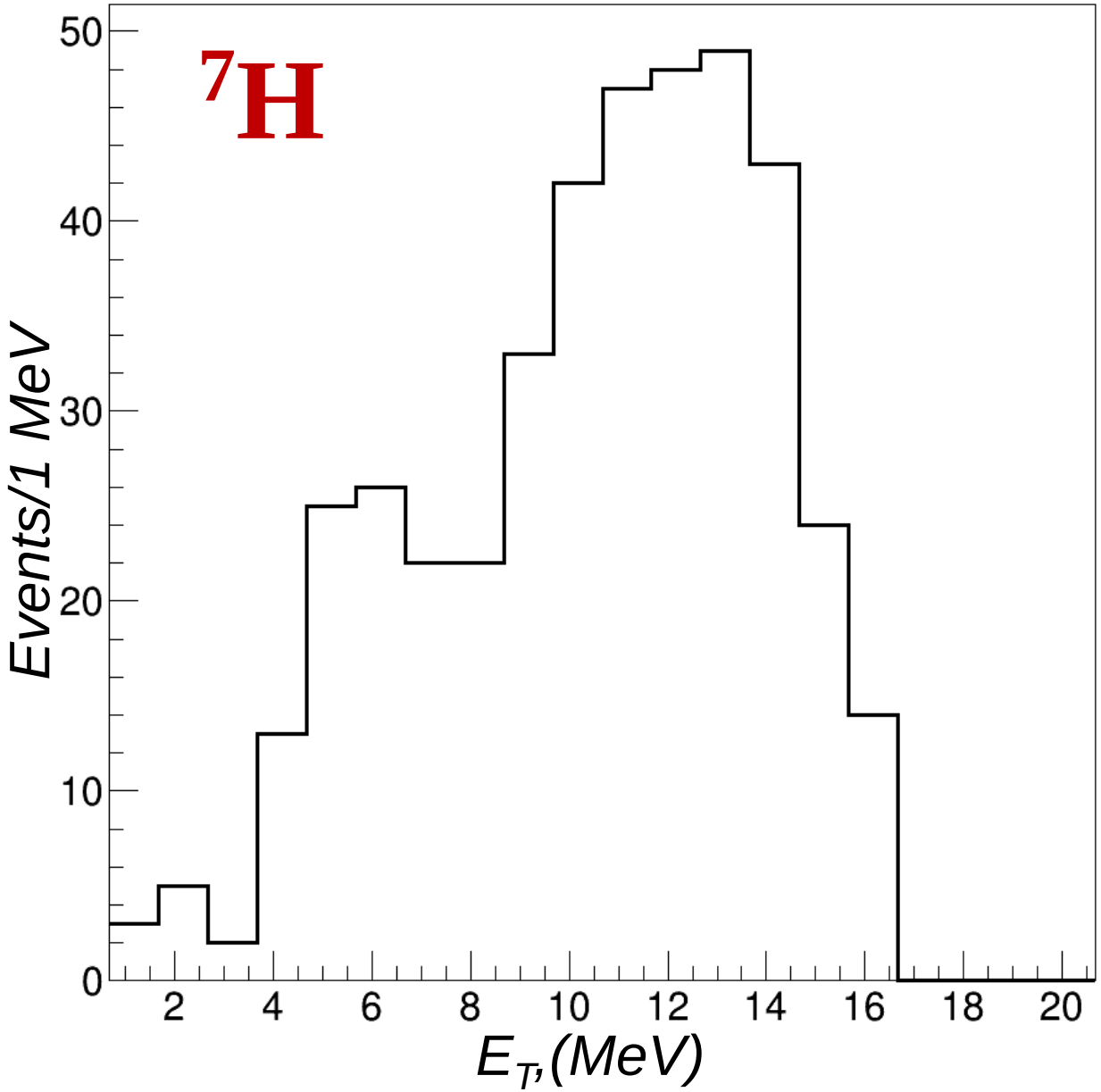
^{7}H population in **^{2}H(^{8}He,^{3}He)^{7}H** with **^{2}H(^{10}Be,^{3}He)^{9}Li** reference reaction

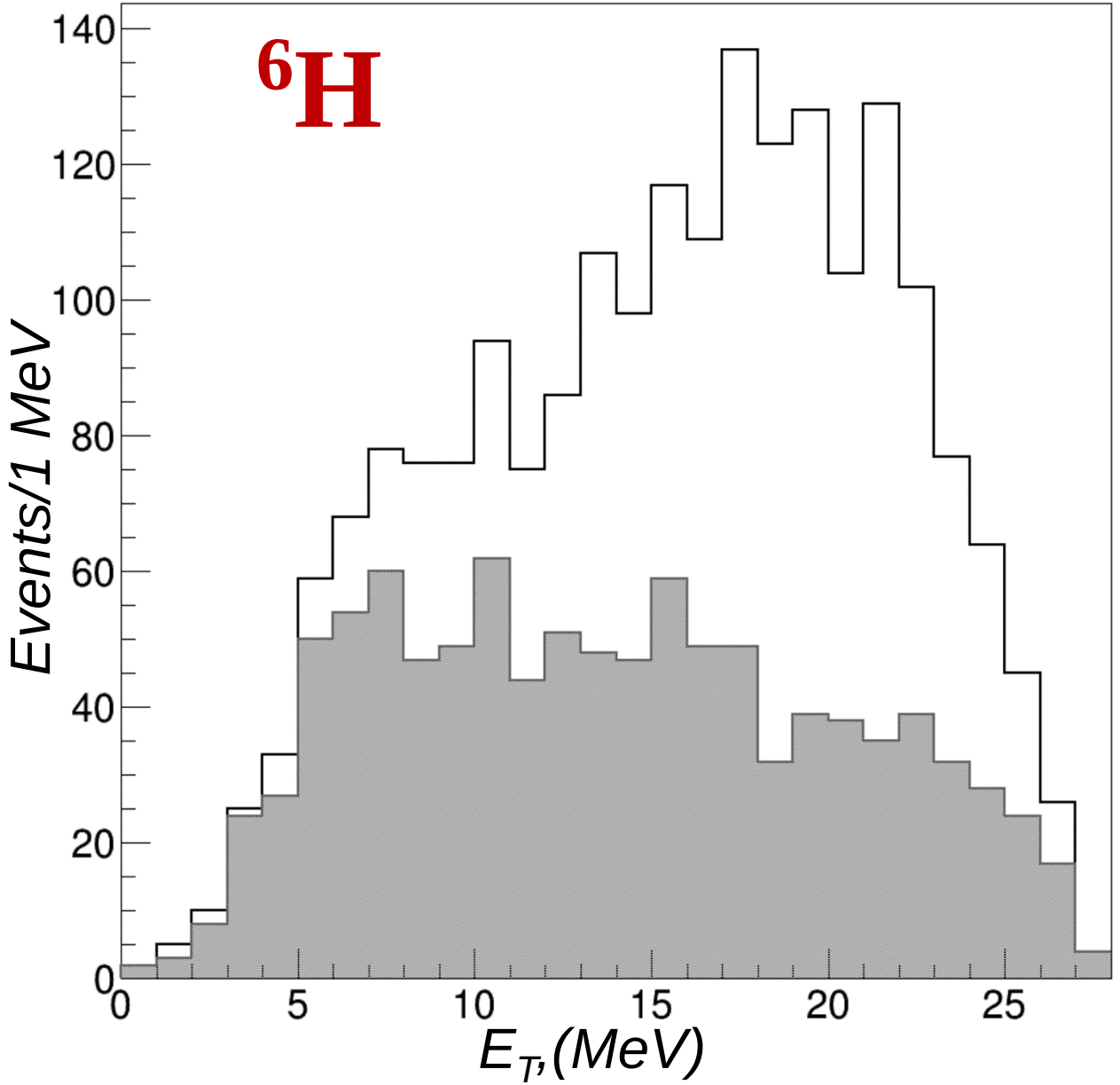
[I. A. Muzalevskii, et al., "Resonant states in ^{7}H: Experimental studies of the ^{2}H(^{8}He,^{3}He) reaction", Phys. Rev. C 103, 044313 (2021)]
[A.A. Bezbakh, et al., "Evidence for the First Excited State of ^{7}H", Phys. Rev. Lett. 124, 022502 (2020)]

^{6}H population in **^{2}H(^{8}He,^{4}He)^{6}H** with **^{2}H(^{10}Be,^{4}He)^{8}Li** reference reaction

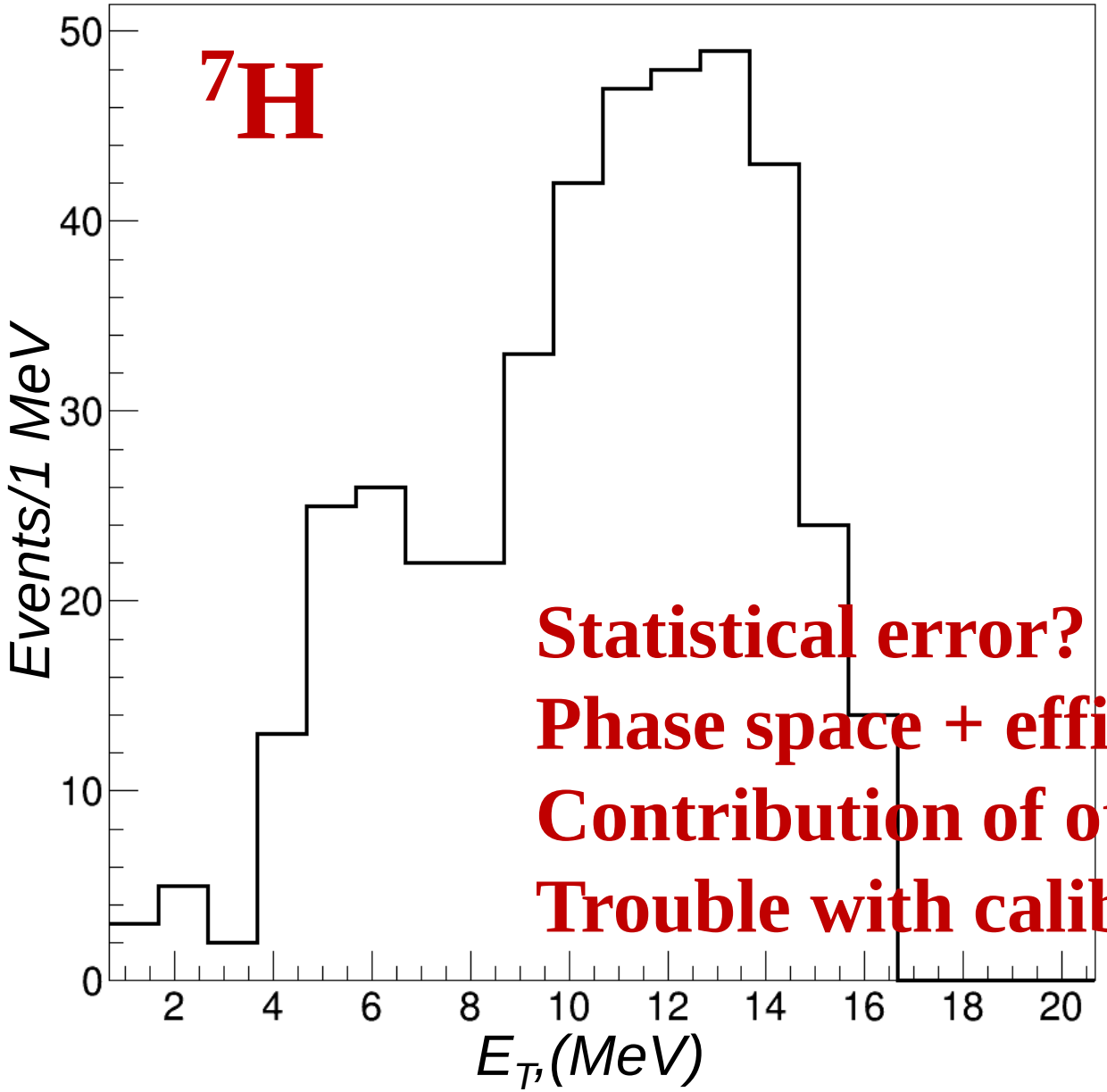
[E. Y. Nikolskii, et al., "The ^{6}H states studied in the d(^{8}He,α) reaction and evidence of extremely correlated character of the ^{5}H ground state, Phys. Rev. Lett. 105, 064605 (2022)]

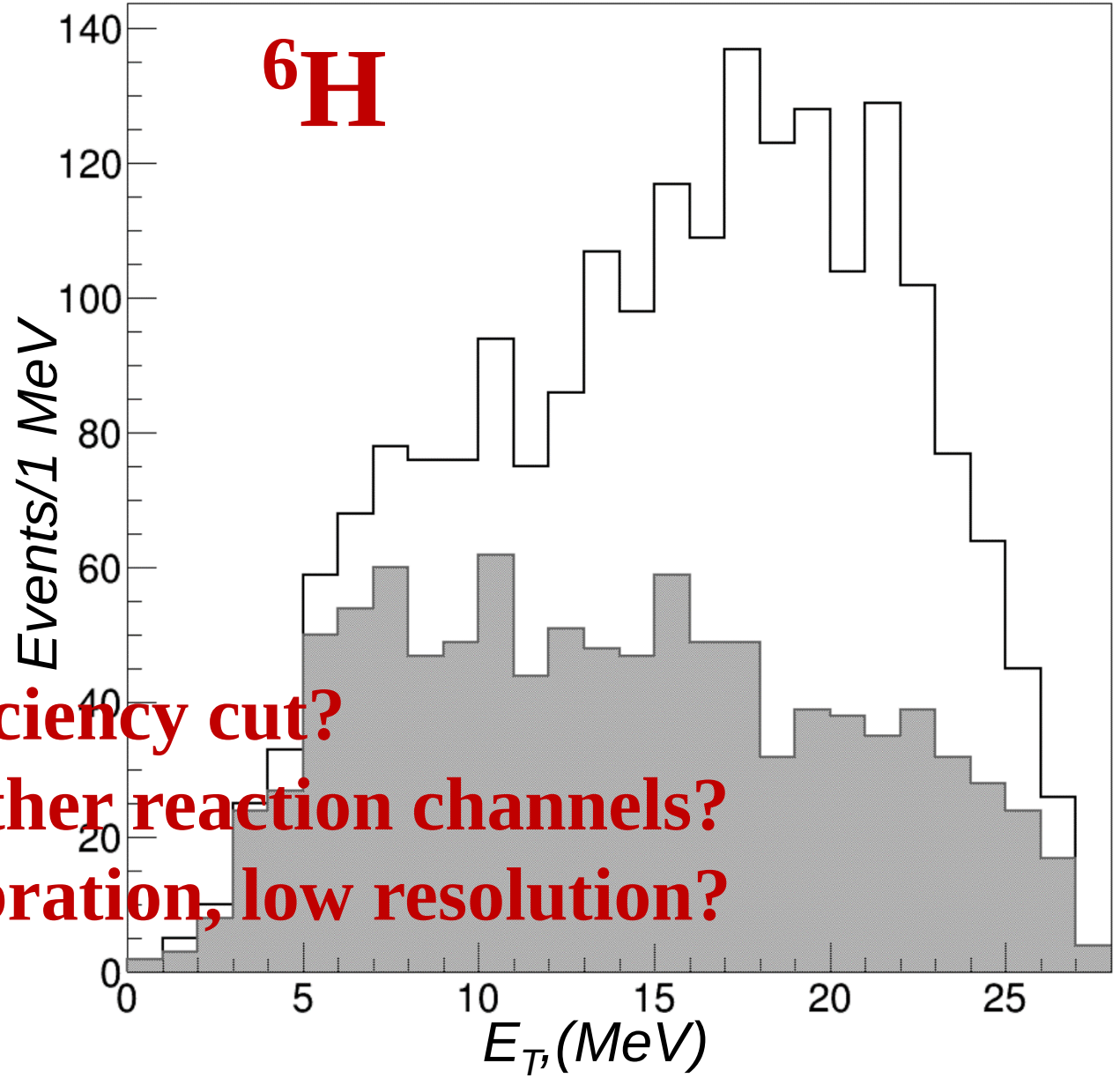
Problem


^{7}H
Events/1 MeV
E_T,(MeV)
0
10
20
30
40
50
2
4
6
8
10
12
14
16
18
20


^{6}H
Events/1 MeV
E_T,(MeV)
0
20
40
60
80
100
120
140
0
5
10
15
20
25

Problem





Statistical error?

Phase space + efficiency cut?

Contribution of other reaction channels?

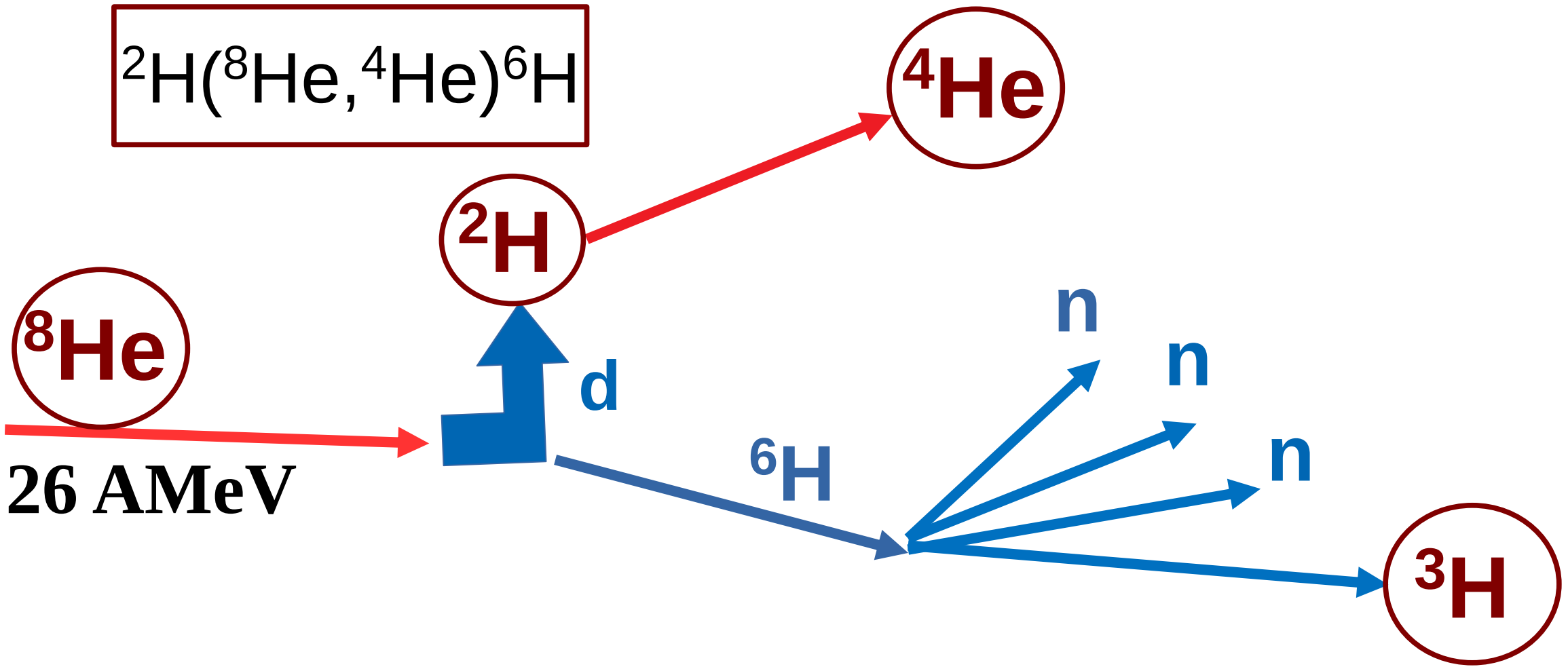
Trouble with calibration, low resolution?

Methods

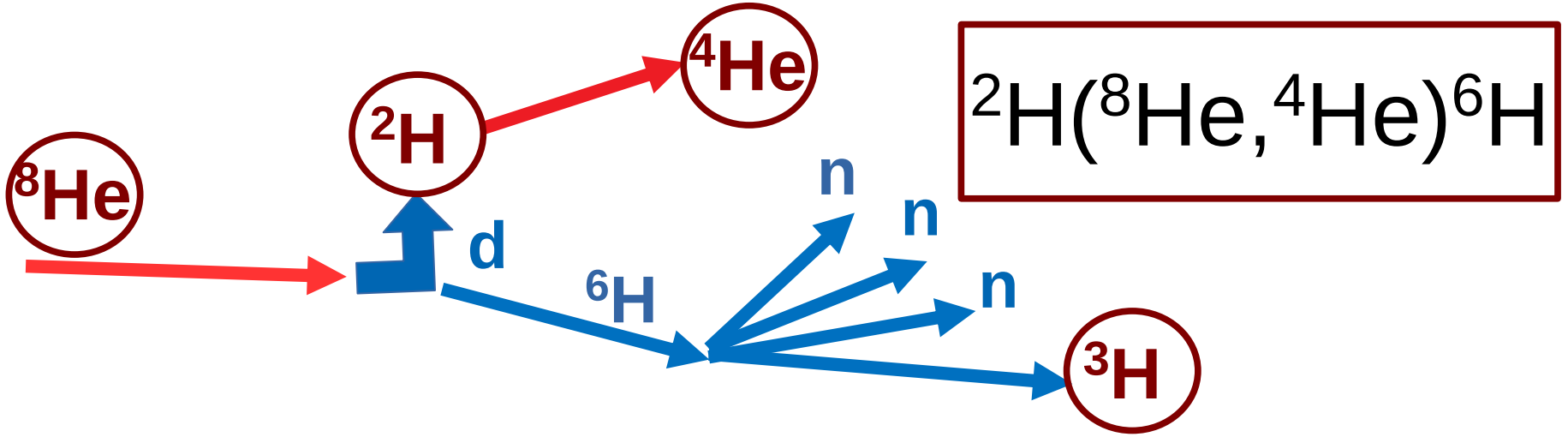
- Angular analysis
- Statistical analysis

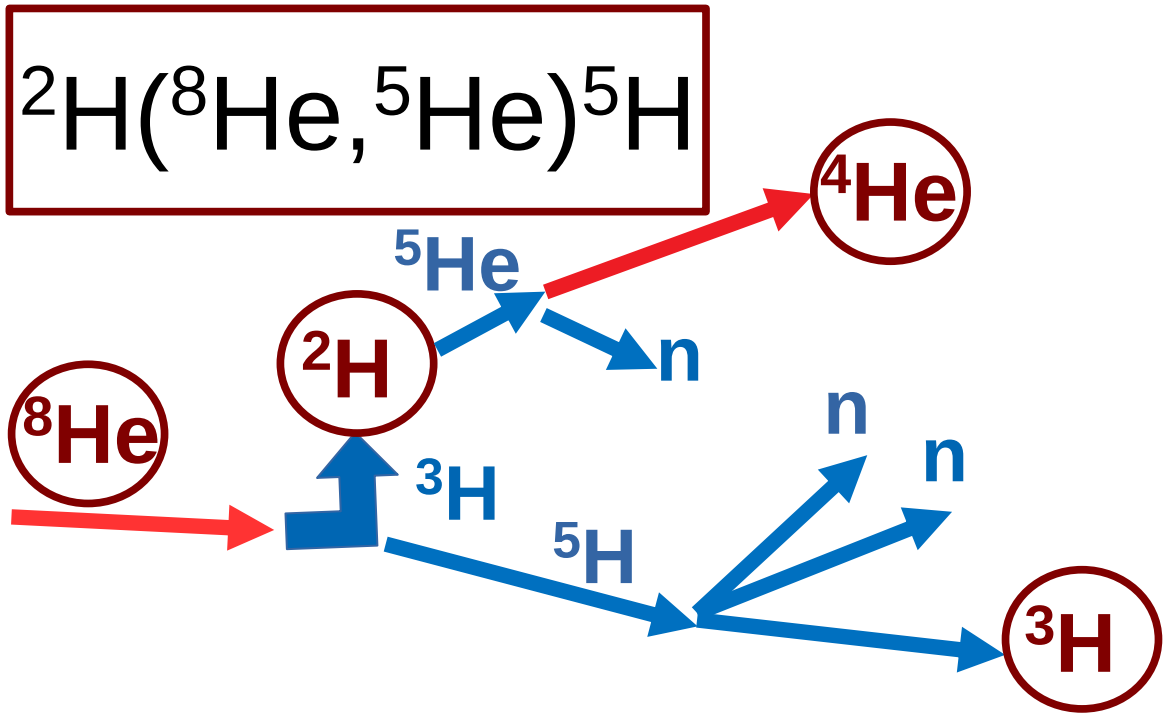
- **Correlations channel analysis**
- **Reference reaction analysis**

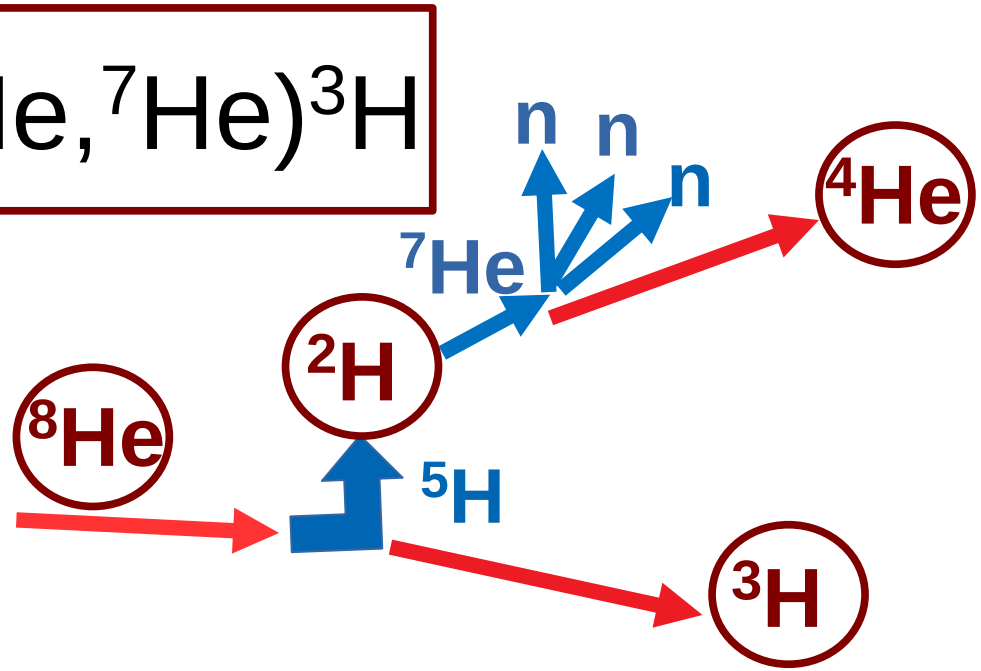
^{6}H channel identification



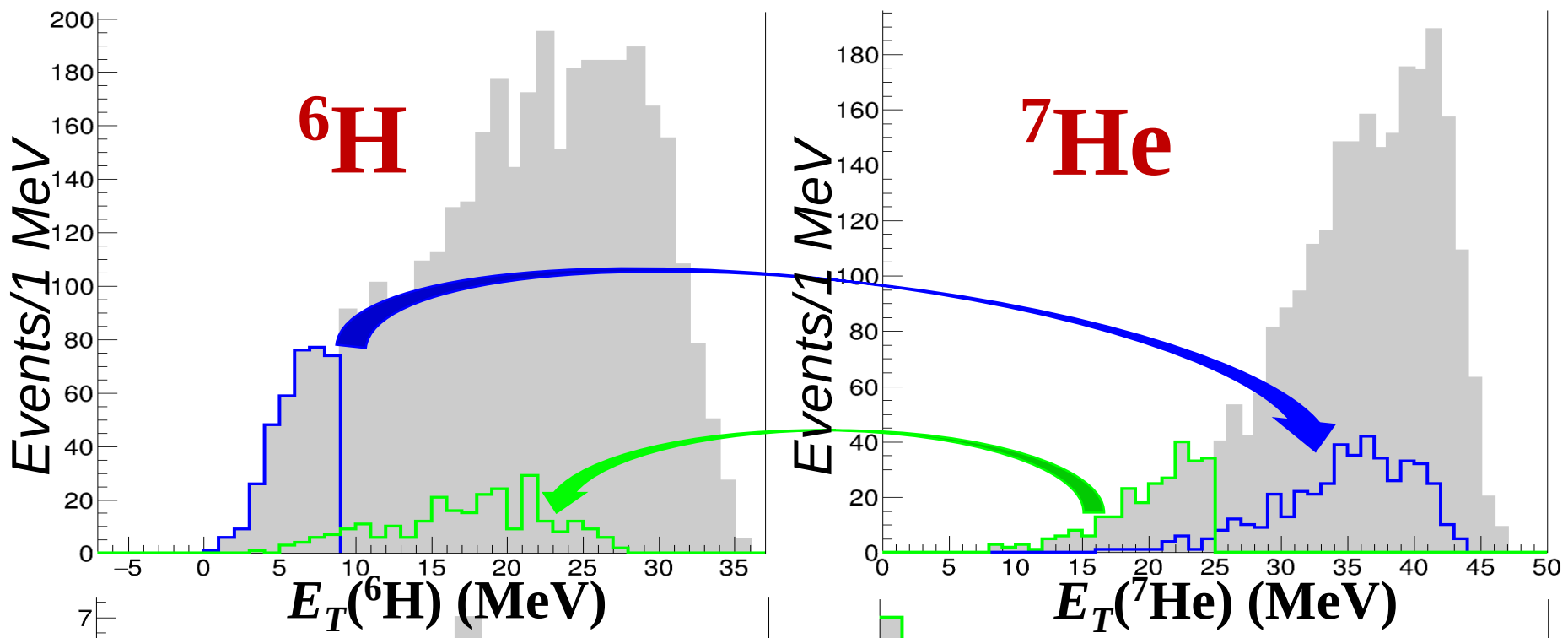
Correlation channels



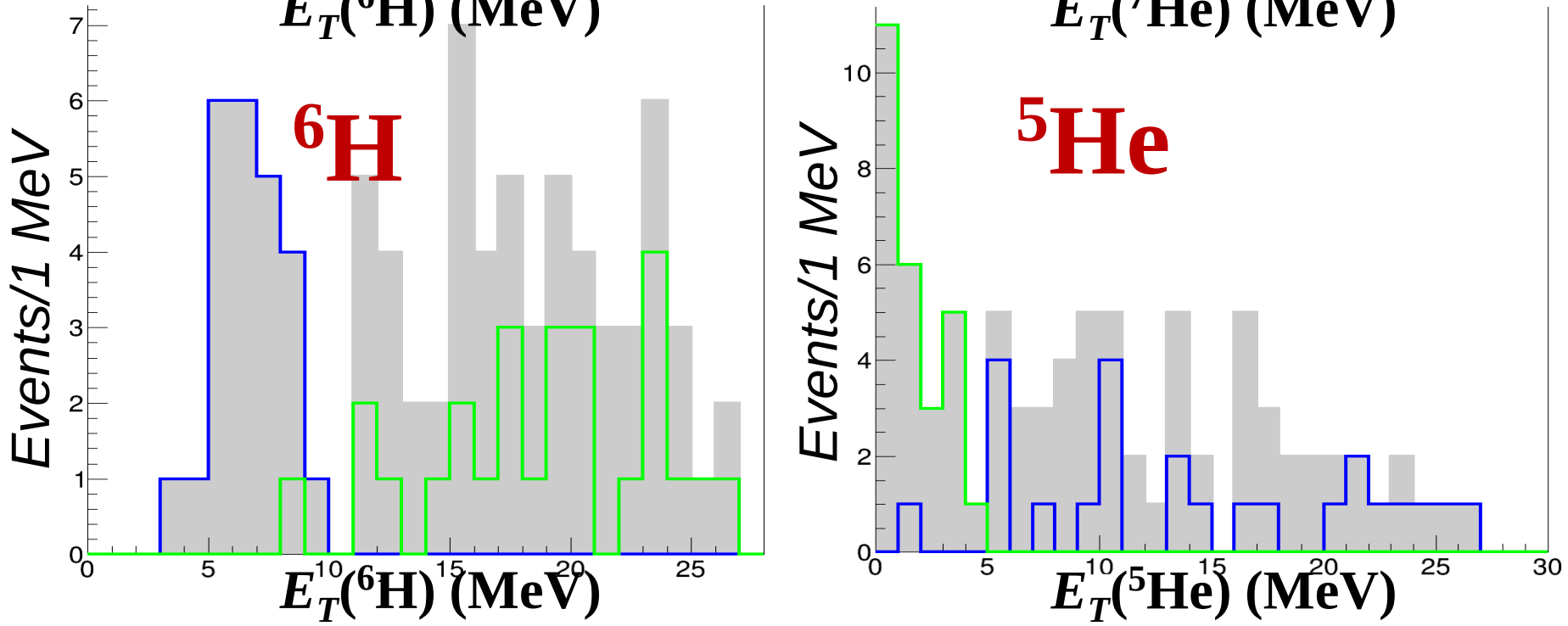




^{2}H(^{8}He,^{4}He)$^{\mathbf{6}}$**H**
^{2}H(^{8}He,$^{\mathbf{7}}$**He**)^{3}H



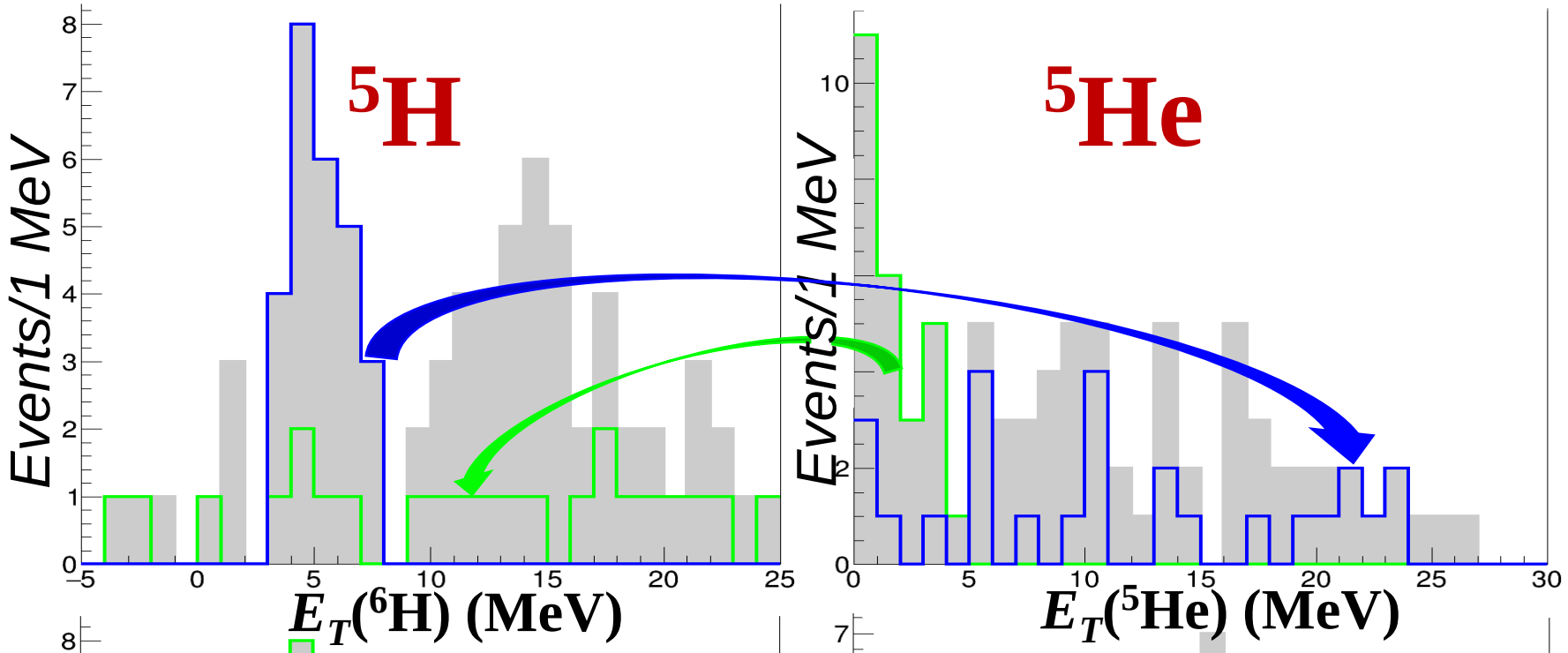
^{2}H(^{8}He,^{4}He)$^{\mathbf{6}}$**H**
^{2}H(^{8}He,$^{\mathbf{5}}$**He**)^{5}H

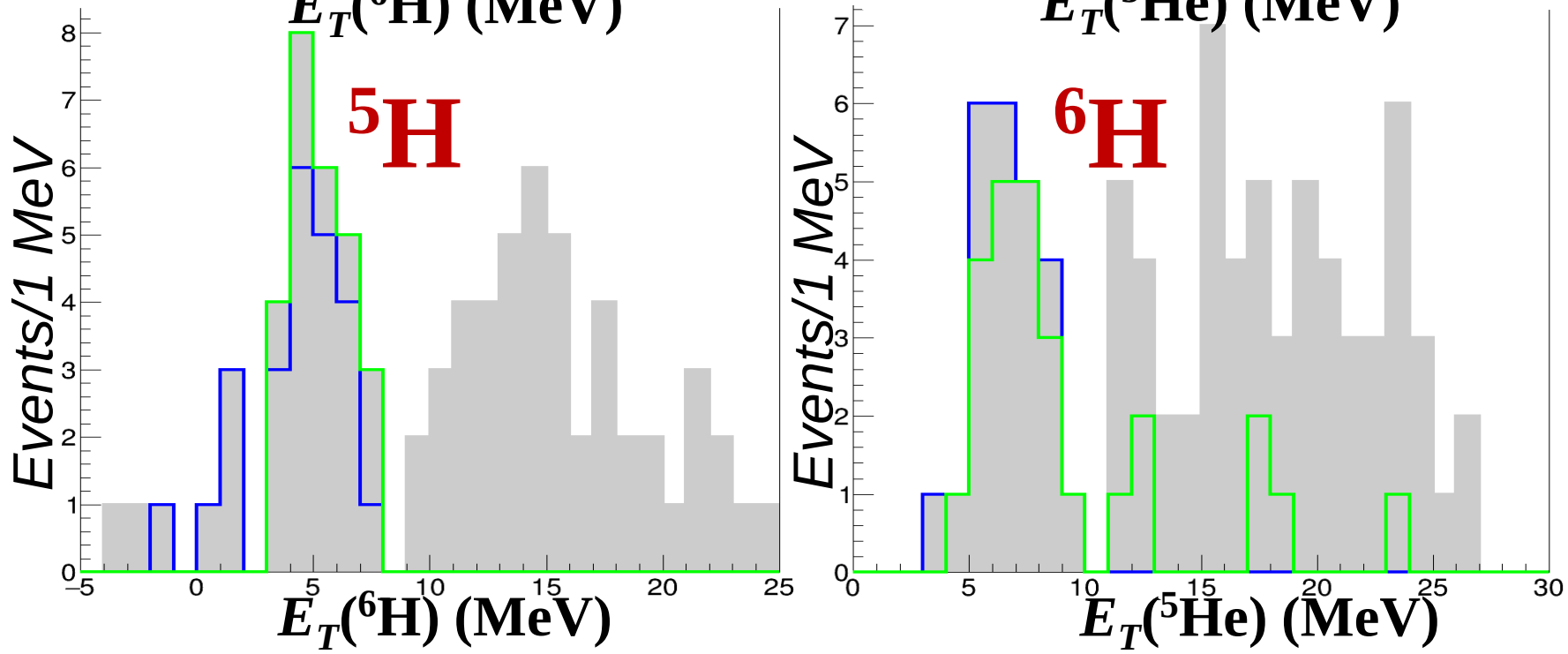


$^{2}H(^{8}He,^{5}\mathbf{He})^{5}\mathbf{H}$

$^{2}H(^{8}He,^{4}He)^{6}\mathbf{H}$

$^{6}\mathbf{H} \rightarrow {}^{5}\mathbf{H}+n$





Correlation analysis results

Low energy ^{6}H spectrum

- Excellent ^{2}H(^{8}He,^{4}He)^{6}H channel identification

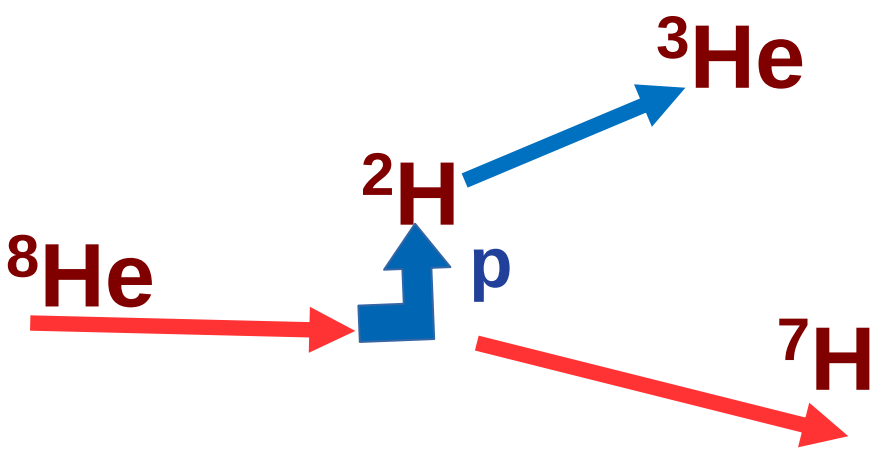
^{5}H MM spectrum is strongly correlated with **^{6}H**

- Another evidence for **^{6}H➡^{5}H(g.s) + n**
- Simulations should be performed

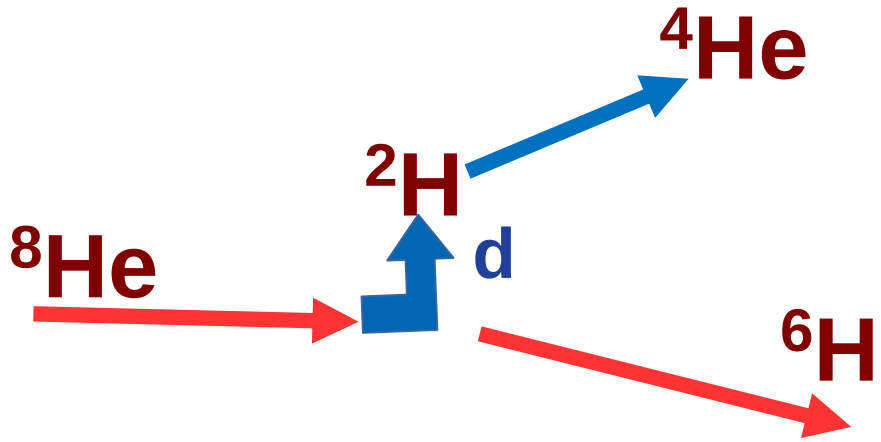
Reference measurements

Main run; missing-mass method

Proton transfer



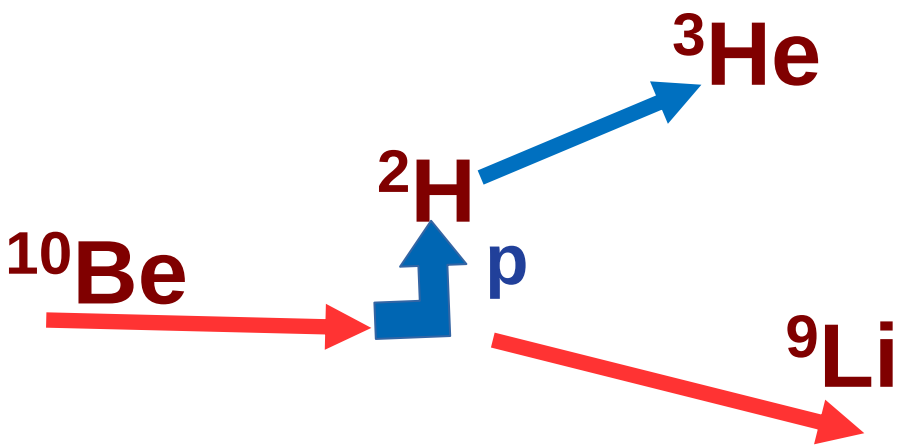
Deutron transfer



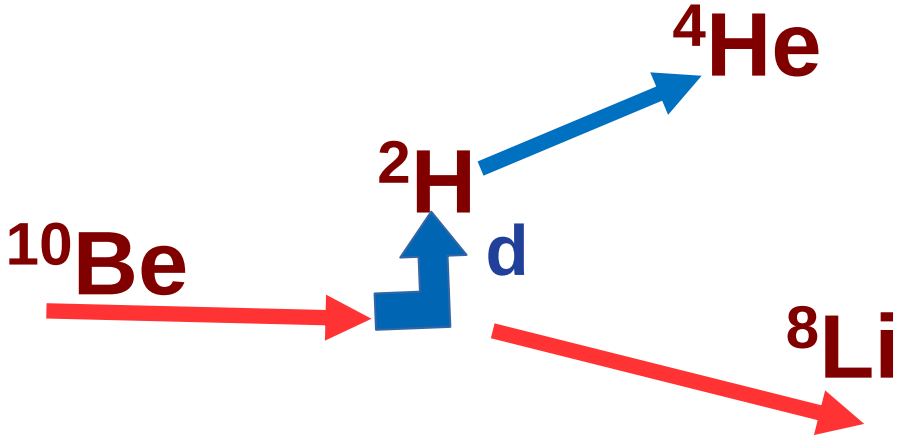
Reference measurements

Reference run; missing-mass method

Proton transfer



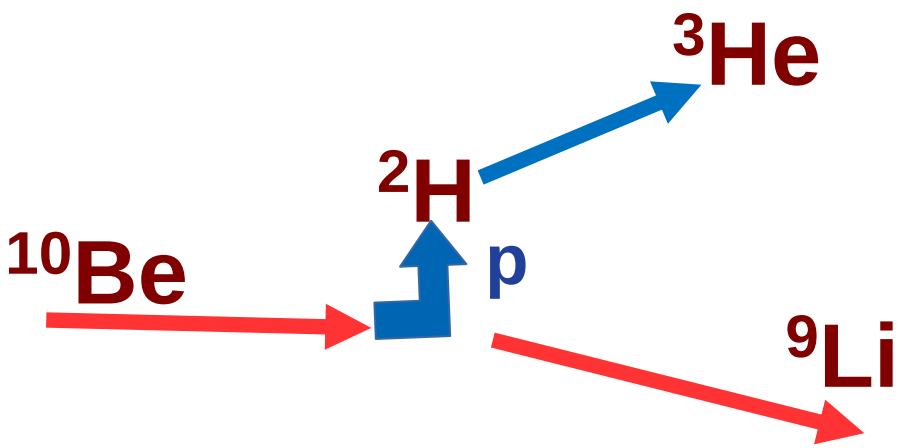
Deutron transfer



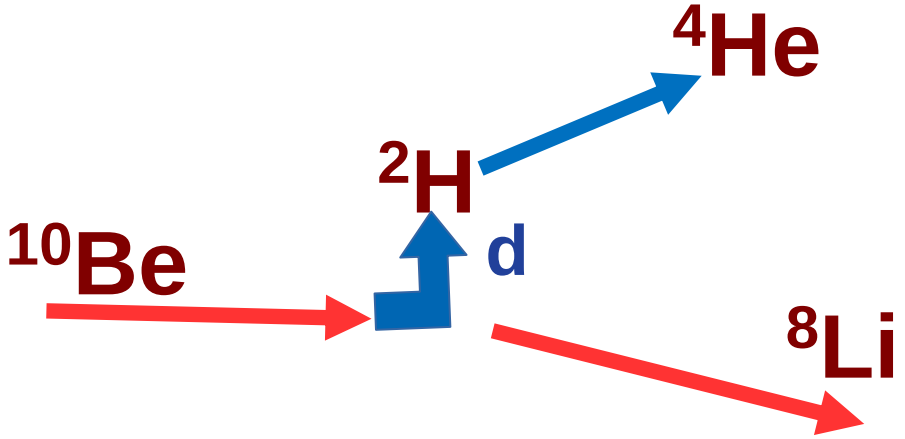
Reference measurements

Reference run; missing-mass method

Proton transfer

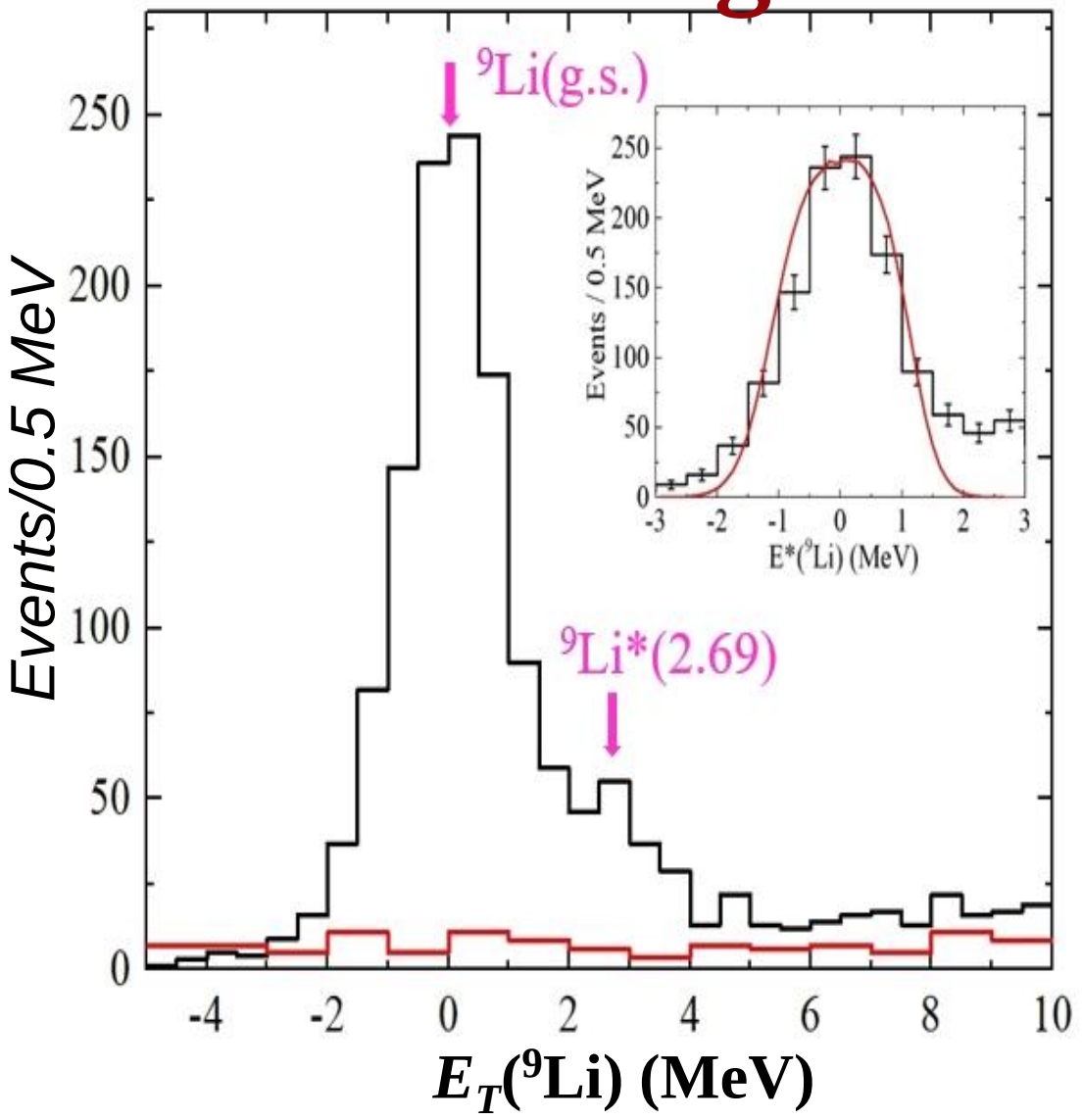


Deutron transfer

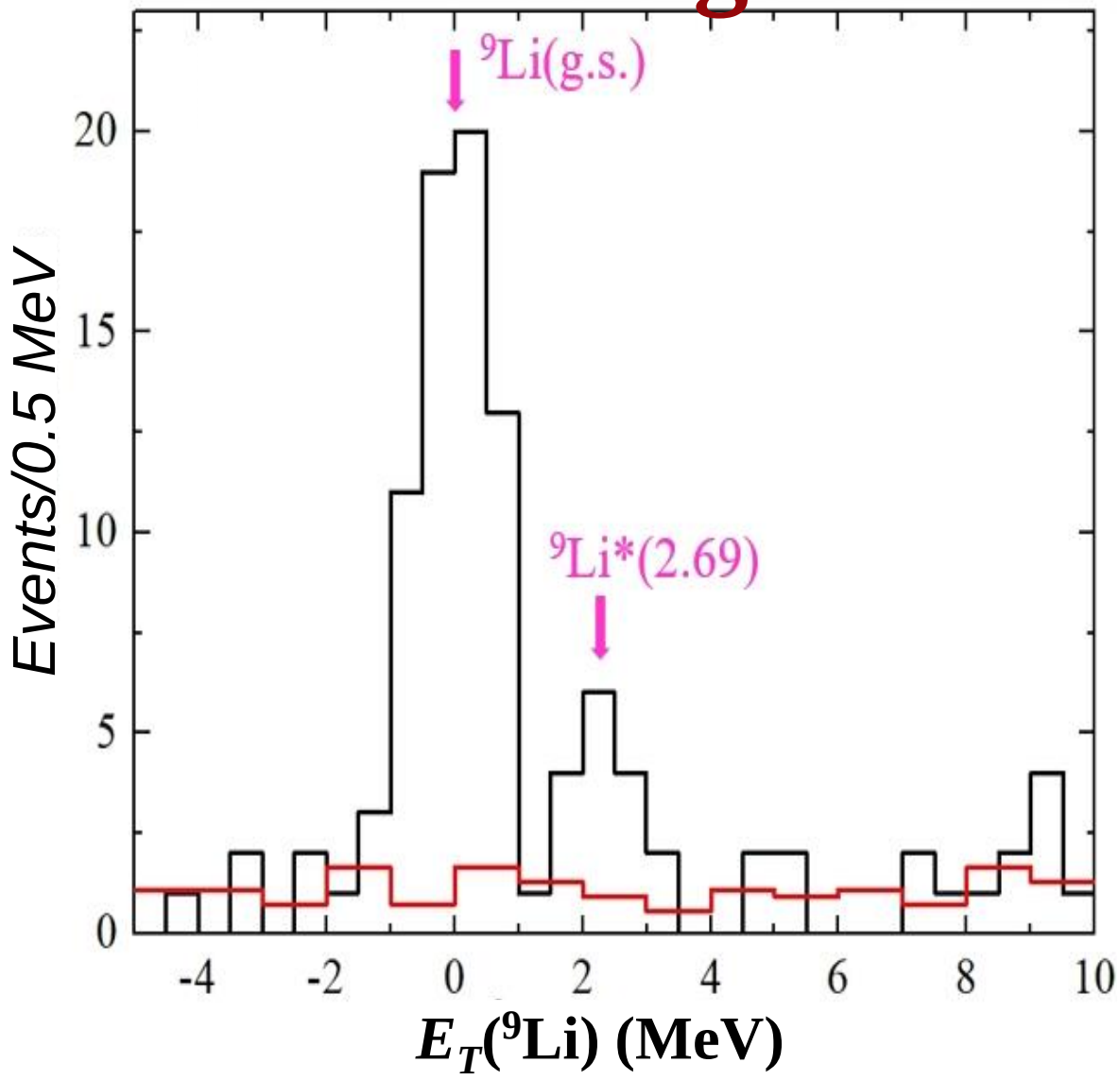


- Stable long-lived reaction products
- Registration of all reaction products
- Well-known structure
- High cross section; high statistics

Thick target

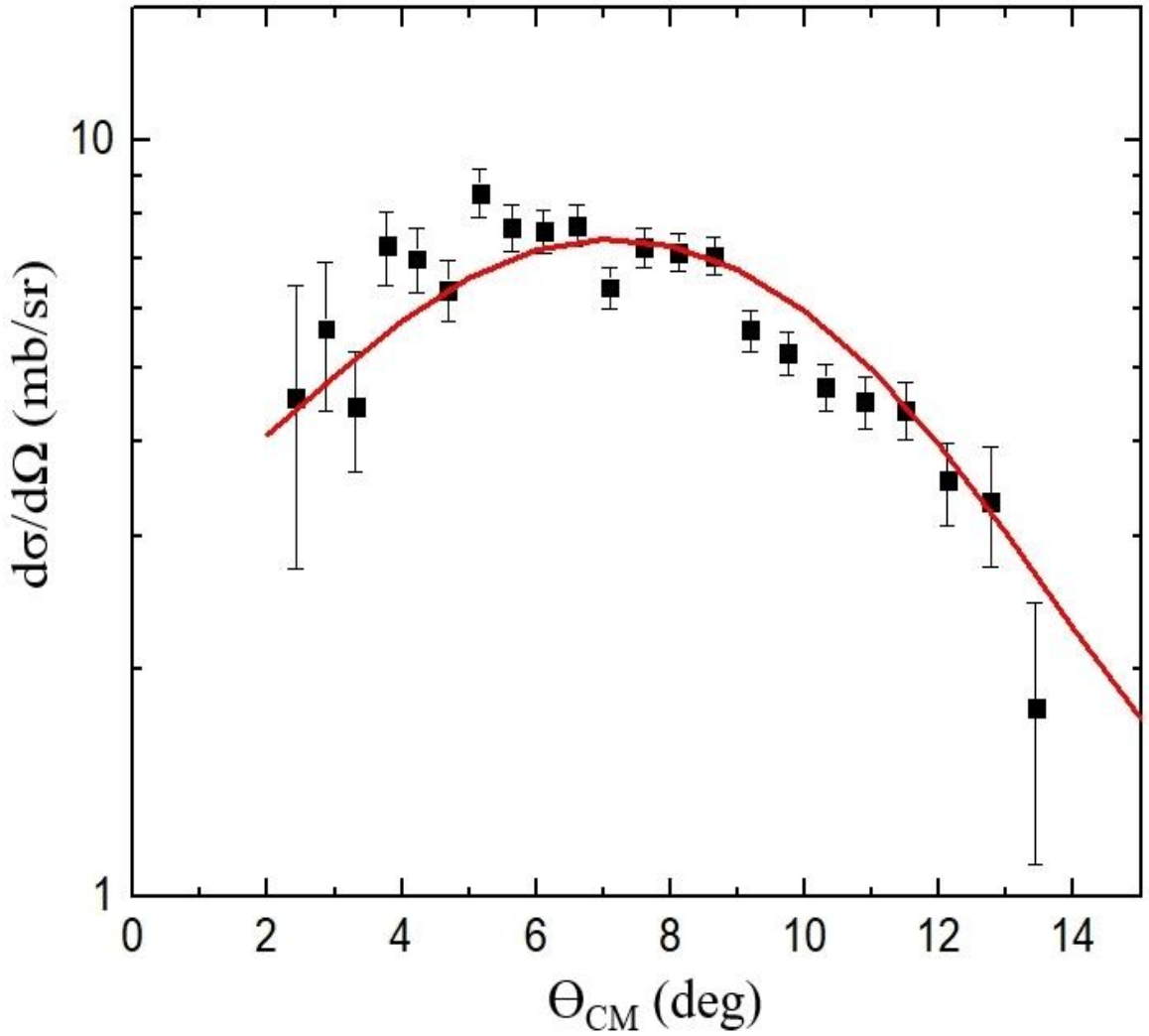


Thin target



- Population of ^{9}Li ground and (1/2-) states
- MC simulation reproduced the experimental MM resolution

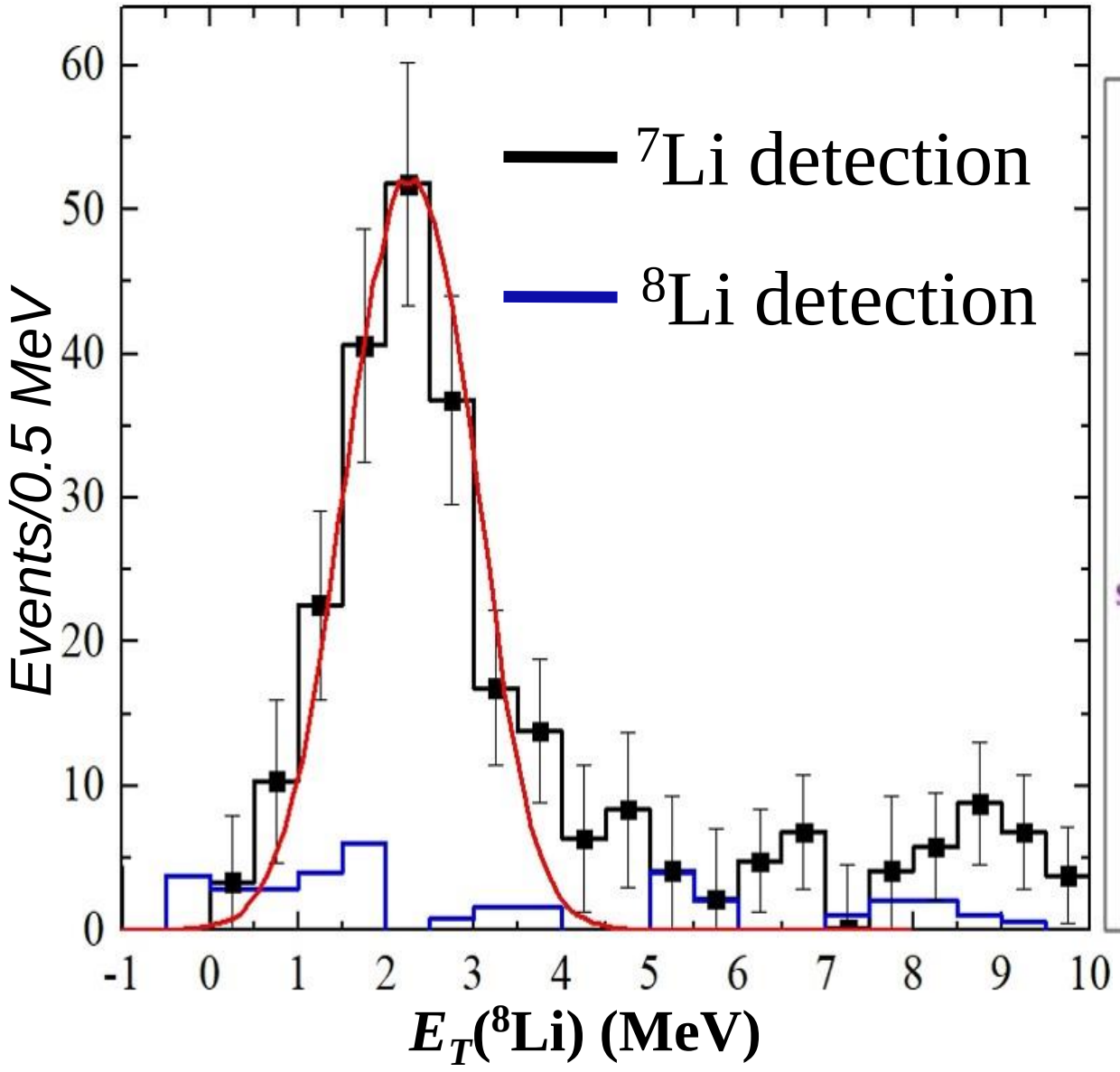
^{9}Li results, reference to ^{7}H



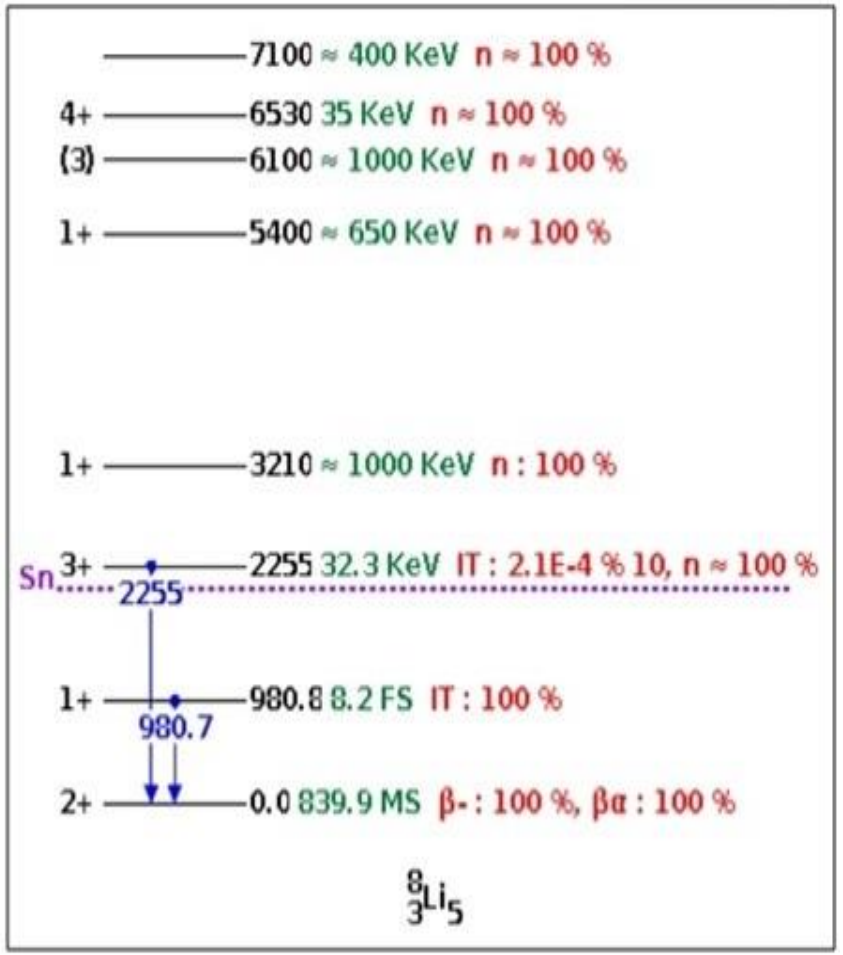
Agreement with *Cenxi Yuan et al., PRC* ***85****, 064324 (2012)*

d-^{3}He channel tested

- **MM spectrum**
- **Resolution**
- **Cross-section**



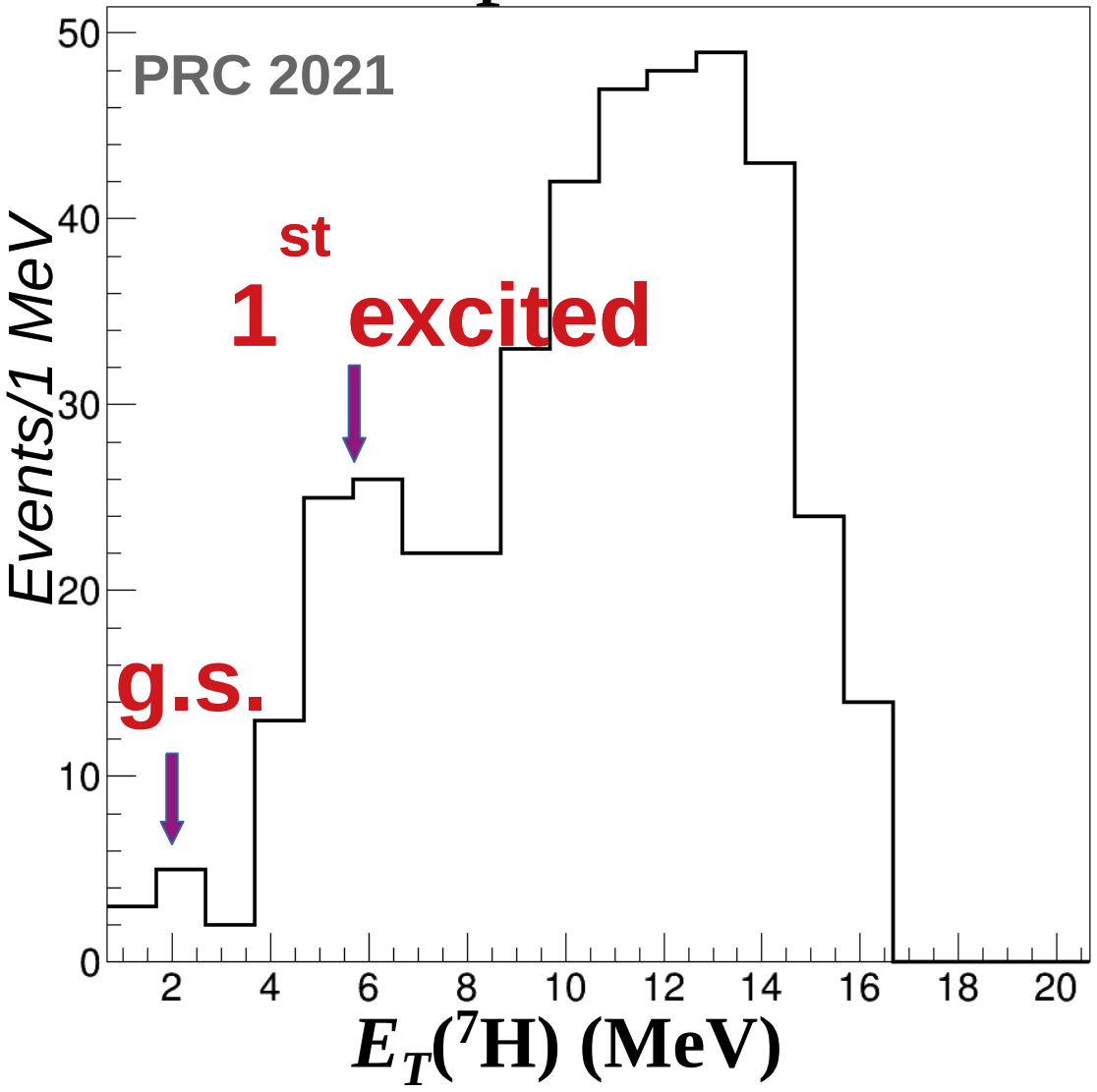
^{8}Li level scheme



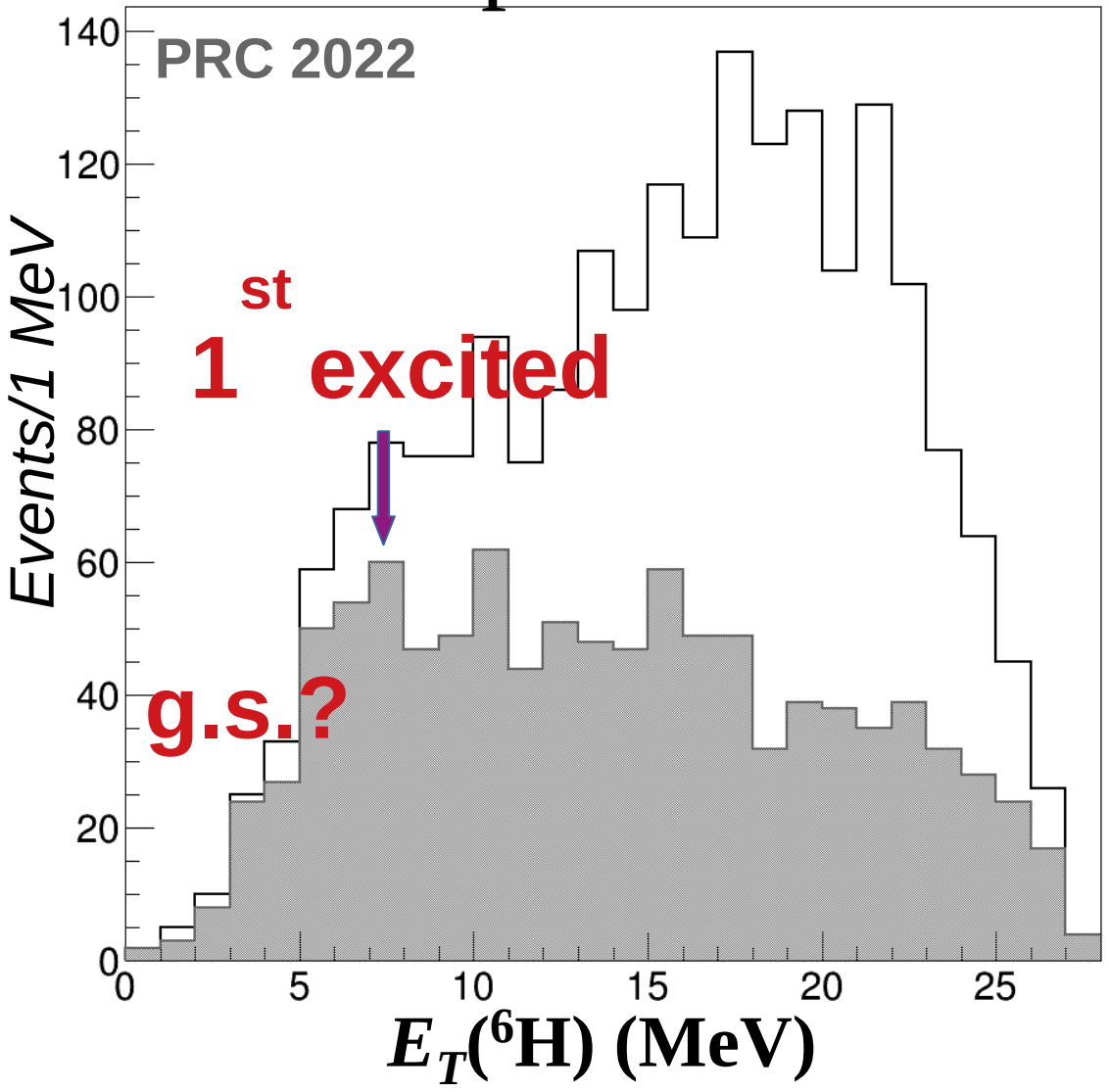
- Population of ^{8}Li (3+) state. Absence of ^{8}Li due to parity violation
- MC simulation reproduced the experimental MM resolution

Fresh achievements

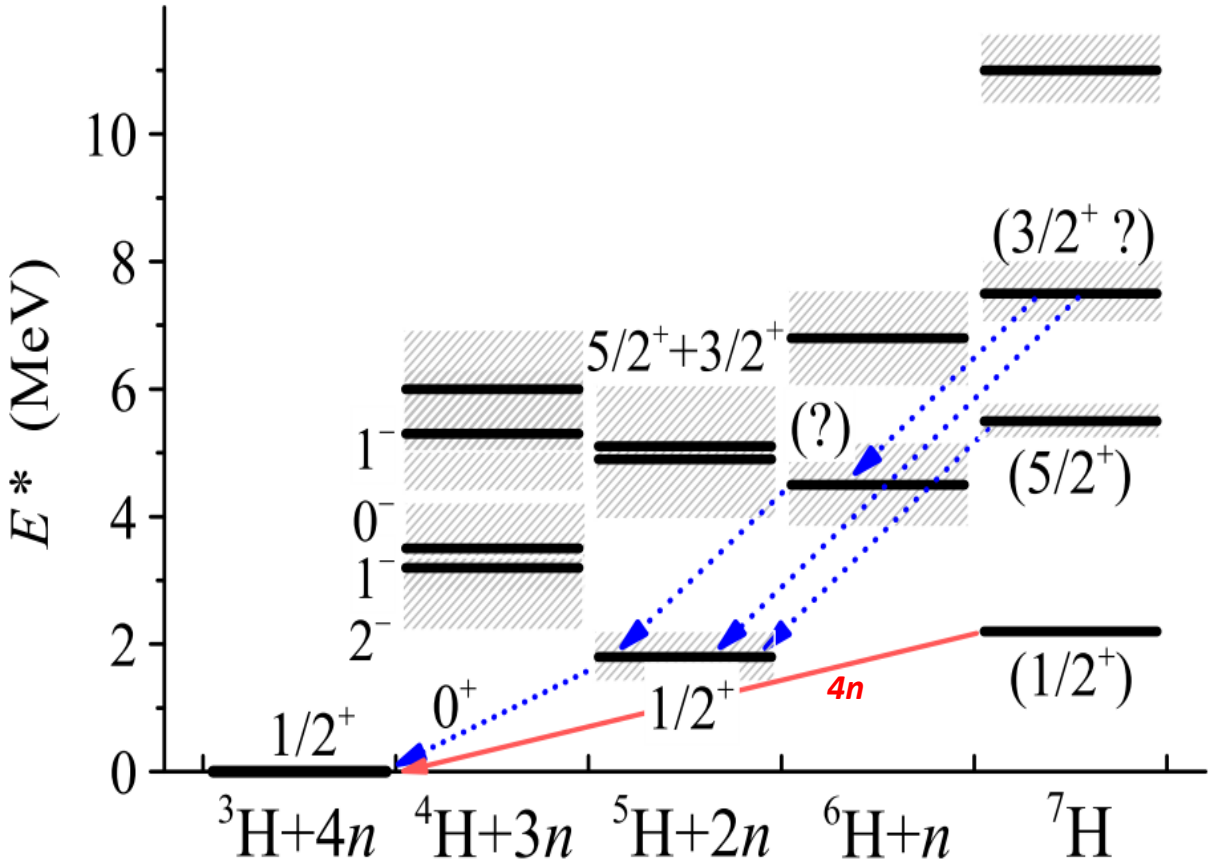
^{7}H spectrum



^{6}H spectrum



Light exotic nuclei today



New level schemes for all isotopes ^{3}H-^{7}H

^{6}H as the evidence of 5-body decay of ^{7}H

The unique true 4n-decay mechanism is proved to be realized for ^{7}H.

This is the first such case found in the nuclide map.

PHYSICAL REVIEW LETTERS **124,** 022502 (2020)

Evidence for the First Excited State of ^{7}H

A. A. Bezbakh,[1,2] V. Chudoba,[1,2,*] S. A. Krupko,[1,3] S. G. Belogurov,[1,4] D. Biare,[1] A. S. Fomichev,[1,5] E. M. Gazeeva,[1] A. V. Gorshkov,[1] L. V. Grigorenko,[1,4,6] G. Kaminski,[1,7] O. A. Kiselev,[8] D. A. Kostyleva,[8,9] M. Yu. Kozlov,[10] B. Mauyey,[1,11] I. Mukha,[8] I. A. Muzalevskii,[1,2] E. Yu. Nikolskii,[6,1] Yu. L. Parfenova,[1] W. Piatek,[1,7] A. M. Quynh,[1,12] V. N. Schetinin,[10] A. Serikov,[1] S. I. Sidorchuk,[1] P. G. Sharov,[1,2] R. S. Slepnev,[1] S. V. Stepantsov,[1] A. Swiercz,[1,13] P. Szymkiewicz,[1,13] G. M. Ter-Akopian,[1,5] R. Wolski,[1,14] B. Zalewski,[1,7] and M. V. Zhukov[15]

PHYSICAL REVIEW C **103**, 044313 (2021)

Resonant states in ^{7}H: Experimental studies of the ^{2}H(^{8}He, ^{3}He) reaction

I. A. Muzalevskii,[1,2,*] A. A. Bezbakh,[1,2] E. Yu. Nikolskii,[3,1] V. Chudoba,[1,2] S. A. Krupko,[1] S. G. Belogurov,[1,4] D. Biare,[1] A. S. Fomichev,[1,5] E. M. Gazeeva,[1] A. V. Gorshkov,[1] L. V. Grigorenko,[1,4,3] G. Kaminski,[1,6] O. Kiselev,[7] D. A. Kostyleva,[7,8] M. Yu. Kozlov,[9] B. Mauyey,[1,10] I. Mukha,[7] Yu. L. Parfenova,[1] W. Piatek,[1,6] A. M. Quynh,[1,11] V. N. Schetinin,[9] A. Serikov,[1] S. I. Sidorchuk,[1] P. G. Sharov,[1,2] N. B. Shulgina,[3,12] R. S. Slepnev,[1] S. V. Stepantsov,[1] A. Swiercz,[1,13] P. Szymkiewicz,[1,13] G. M. Ter-Akopian,[1,5] R. Wolski,[1,14] B. Zalewski,[1,6] and M. V. Zhukov[15]

PHYSICAL REVIEW C **105**, 064605 (2022)

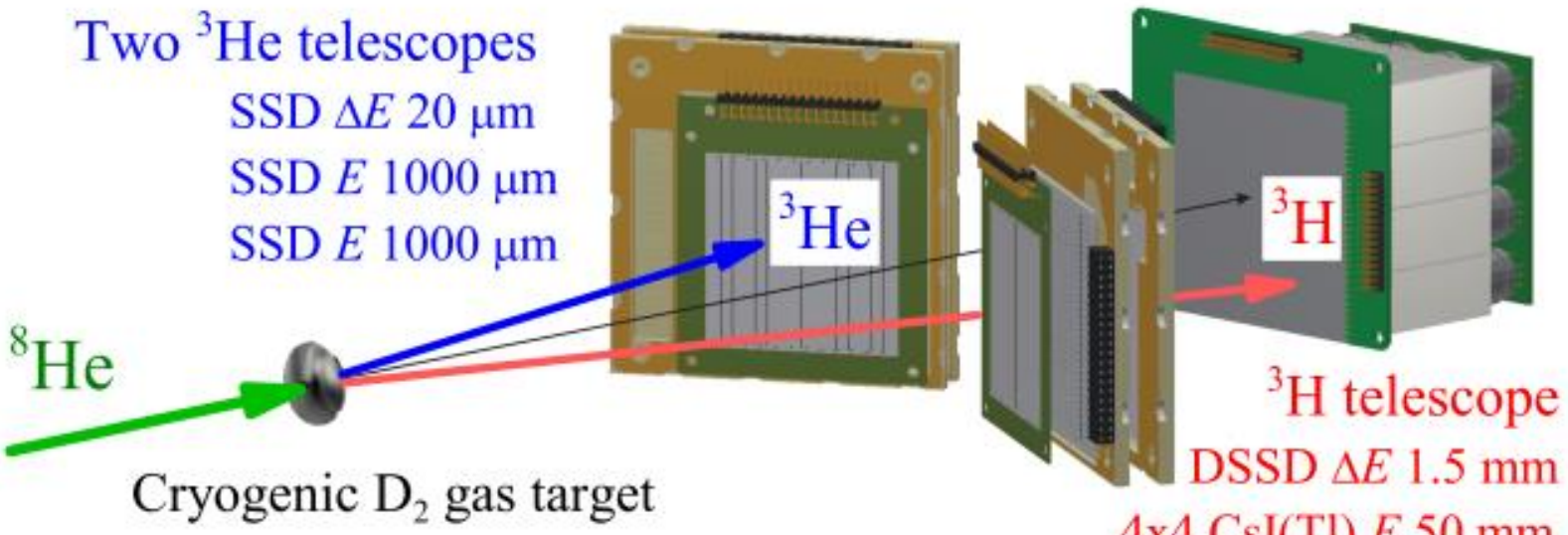
^{6}H states studied in the ^{2}H(^{8}He, ^{4}He) reaction and evidence of an extremely correlated character of the ^{5}H ground state

E. Yu. Nikolskii,[1,2,*] I. A. Muzalevskii,[2,3] A. A. Bezbakh,[2,3] V. Chudoba,[2,3] S. A. Krupko,[2] S. G. Belogurov,[2,4] D. Biare,[2] A. S. Fomichev,[2,5] E. M. Gazeeva,[2] A. V. Gorshkov,[2] L. V. Grigorenko,[2,4,1] G. Kaminski,[2,6] M. Khirk,[7,2] O. Kiselev,[8] D. A. Kostyleva,[8,9] M. Yu. Kozlov,[10] B. Mauyey,[2,11] I. Mukha,[8] Yu. L. Parfenova,[2] W. Piatek,[2,6] A. M. Quynh,[2,12] V. N. Schetinin,[10] A. Serikov,[2] S. I. Sidorchuk,[2] P. G. Sharov,[2,3] N. B. Shulgina,[1,13] R. S. Slepnev,[2] S. V. Stepantsov,[2] A. Swiercz,[2,14] P. Szymkiewicz,[2,14] G. M. Ter-Akopian,[2,5] R. Wolski,[2,15] B. Zalewski,[2,6] and M. V. Zhukov[16]

Thanks for attention

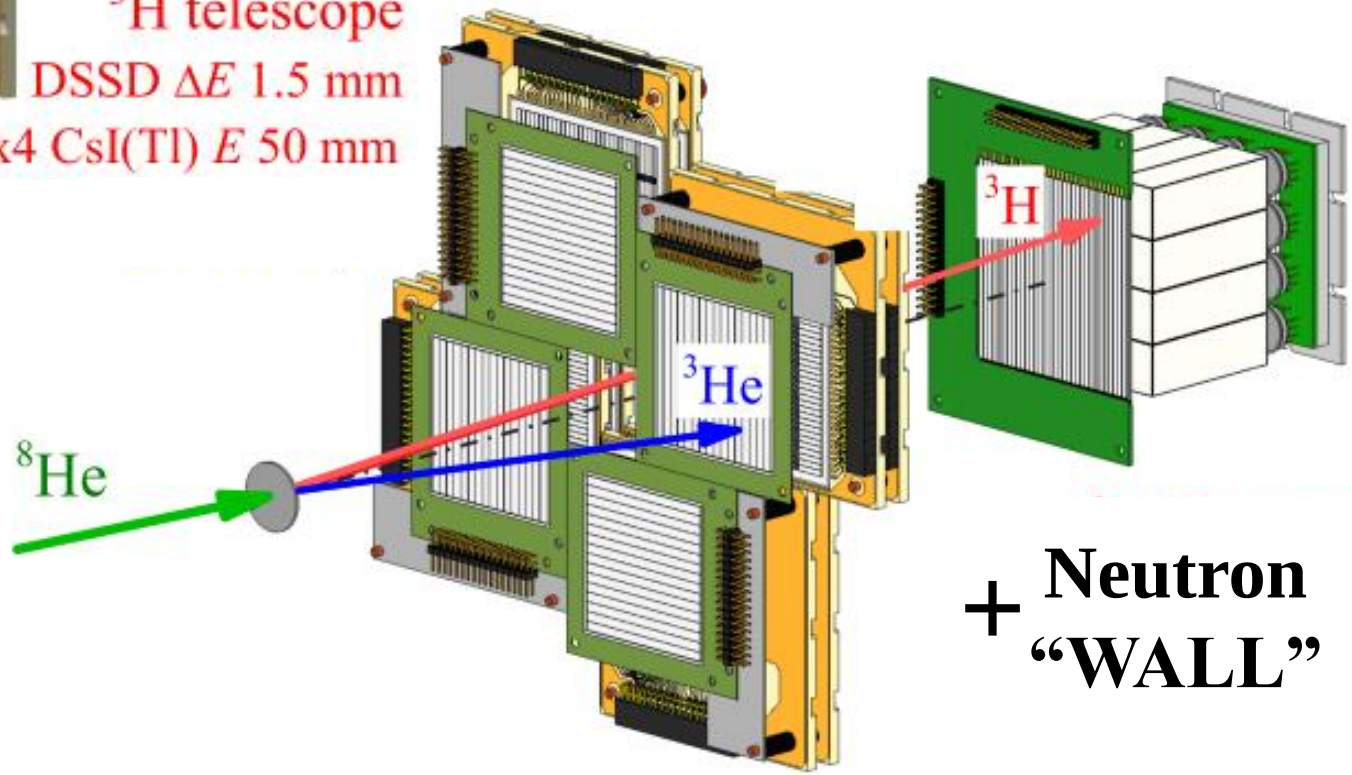
Setup

Run 1
2 weeks
119 ^{3}He-^{3}H coincidences



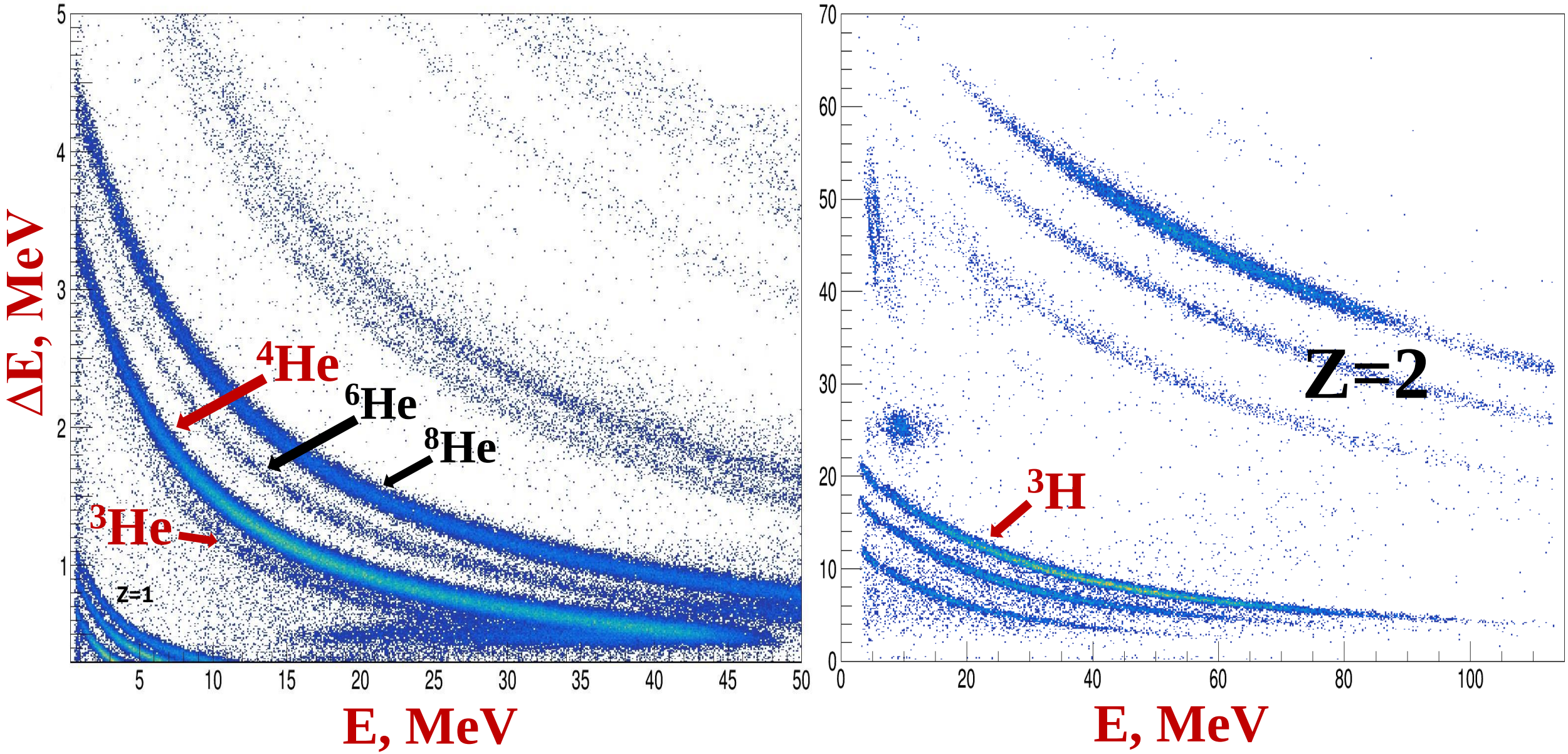
- MM resolution:
  ^{7}H - 1.1 MeV, ^{6}H - 1.5 MeV,
- Efficiency of ^{3,4}He-^{3}H registration~80%
- ^{3}H detection angular/energy resolution~ 0.5 deg / 2%

Run 2
3 weeks,
enhanced angular range and efficiency
378 ^{3}He-^{3}H coincidences



+ Neutron "WALL"

Particle identification

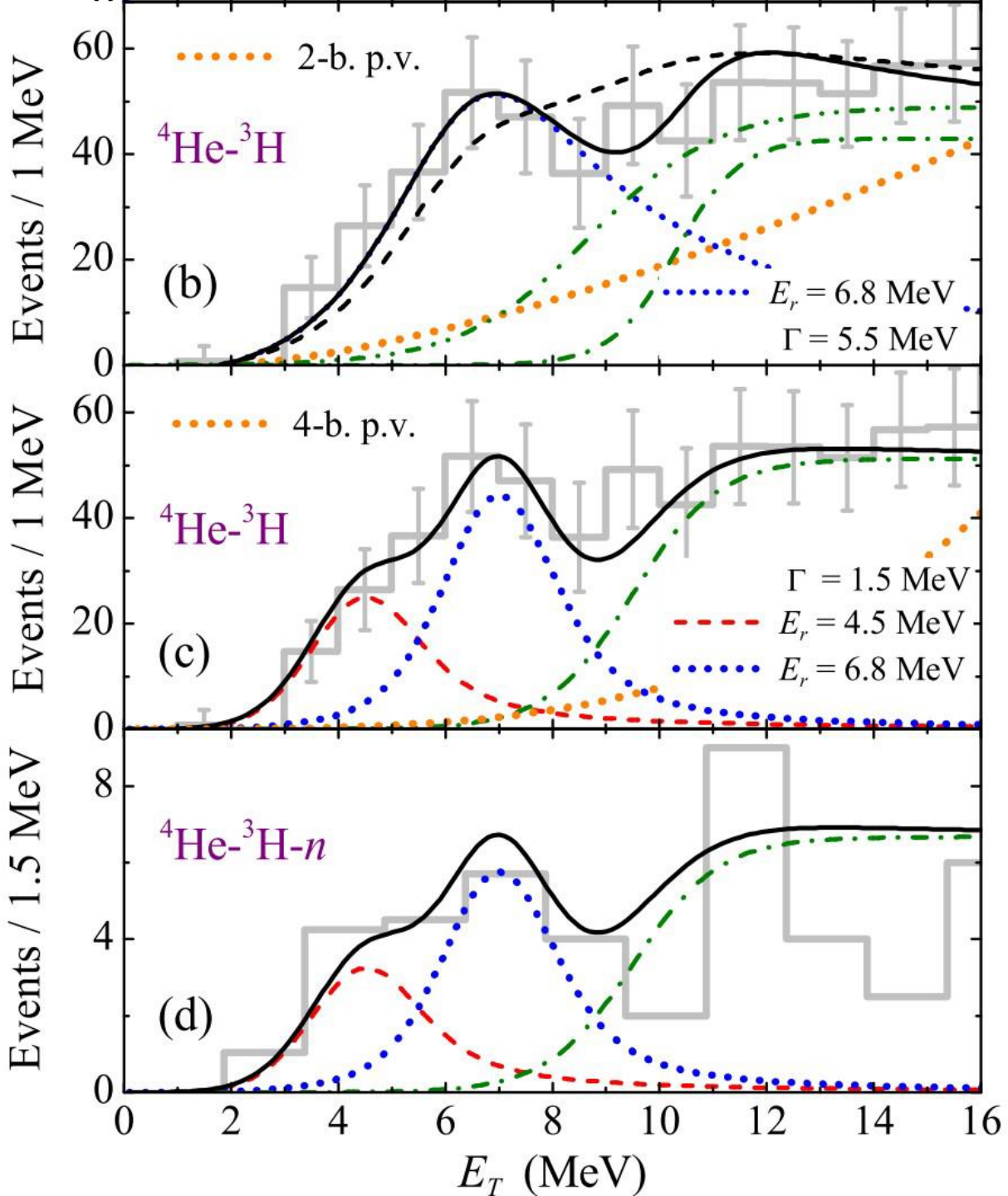


^{6}H results

NO states below 3.5 MeV
($d\sigma/d\Omega < 5$ μb/sr)

Peak at 4-8 MeV (~190 μb/sr):

- 4.5 MeV ground state
- 6.8 MeV excited state



^{7}H results

I. Muzalevskii et al., Phys. Rev. C 103, 044313 (2021)

^{7}H ground state at 2.2(5) MeV

^{7}H excited state at 5.5(3) MeV (possibly doublet at 5.5-7.5 MeV)

Peak at 11(3) MeV