Exploring unbound states of ^{18}C in inverse kinematics with the R^{3}B setup

Martina Feijoo Fontán

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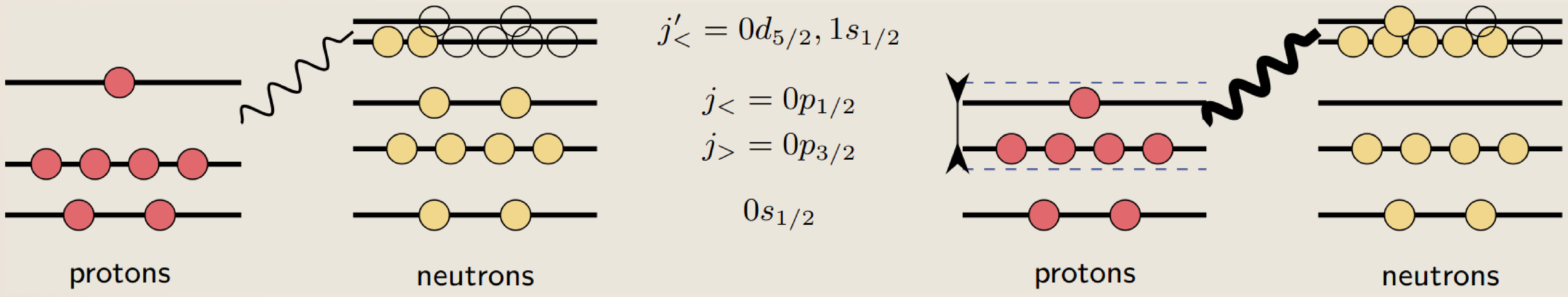
25 1999 2024

Evolution of the p-splitting (Z=6) towards the neutron dripline

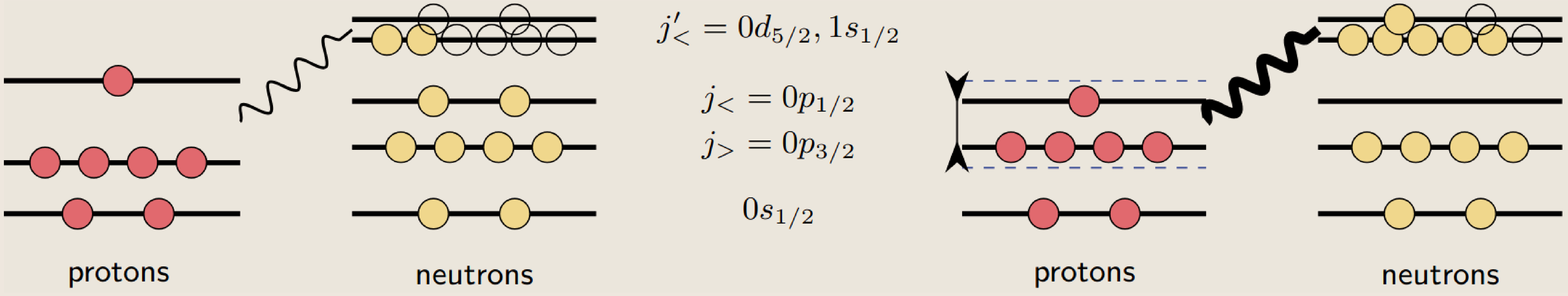


Carbon isotopes

constant
D.T. Tran et al, Nat Comm 9 1594

quenched
I. Syndikus et al, PLB 809 135748

Evolution of the *p*-splitting (Z=6) towards the neutron dripline



$^{X}N(p,2p)^{X-1}C$ -> p removed from $p_{1/2}$ and $p_{3/2}$ orbitals leading to 1+ and 2+ states in even-even C nuclei

Carbon isotopes

constant
D.T. Tran et al, Nat Comm 9 1594

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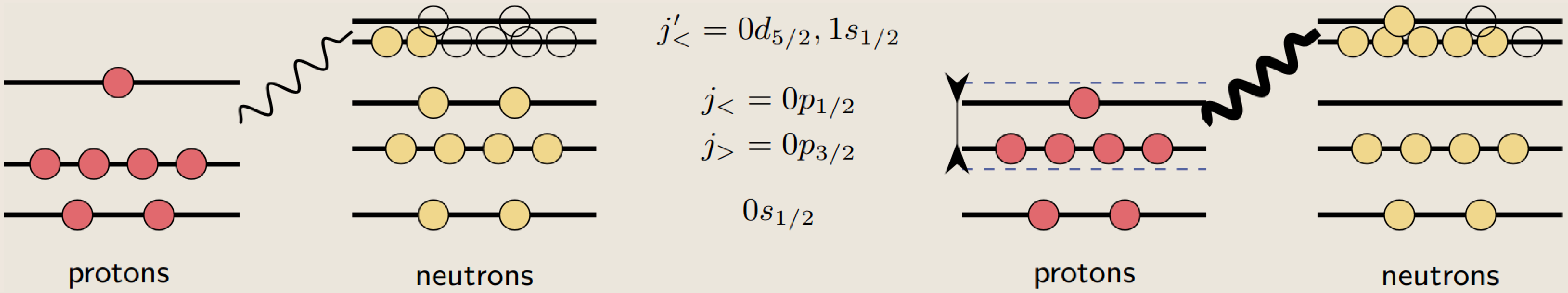
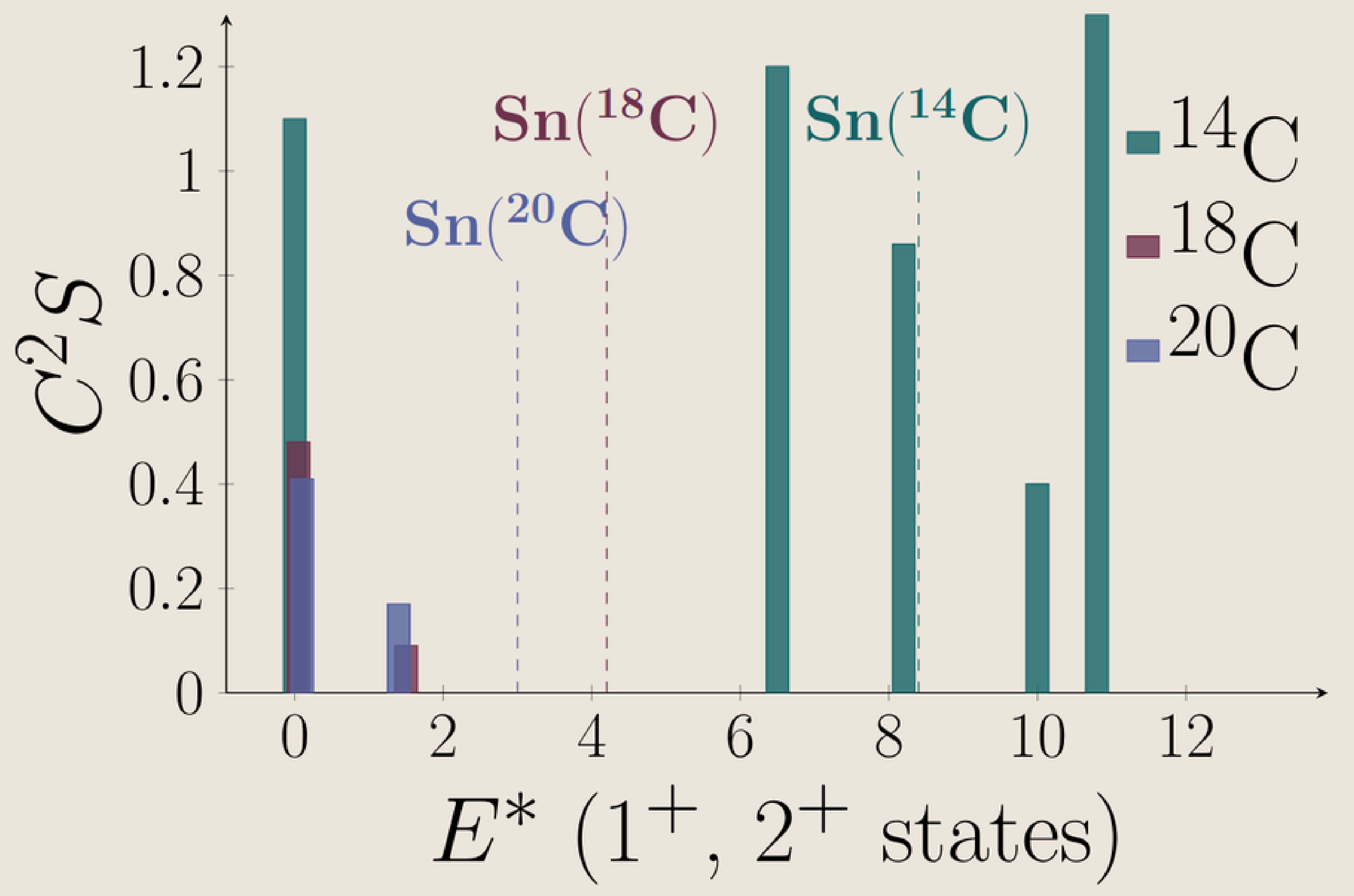
First excited 2+ already studied looking at $C^2S(2+)/C^2S(0+)$

most of the interesting strength is unbound

extend the work for 1n decay

Evolution of the *p*-splitting (Z=6) towards the neutron dripline





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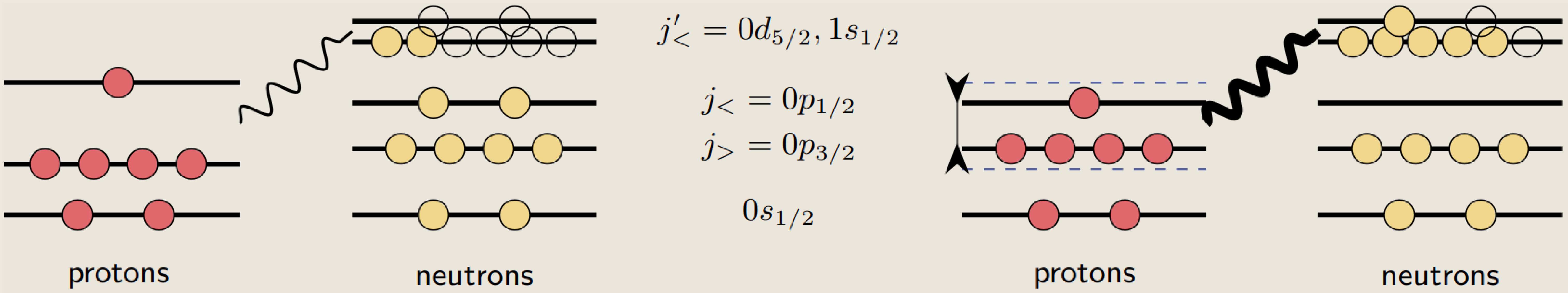

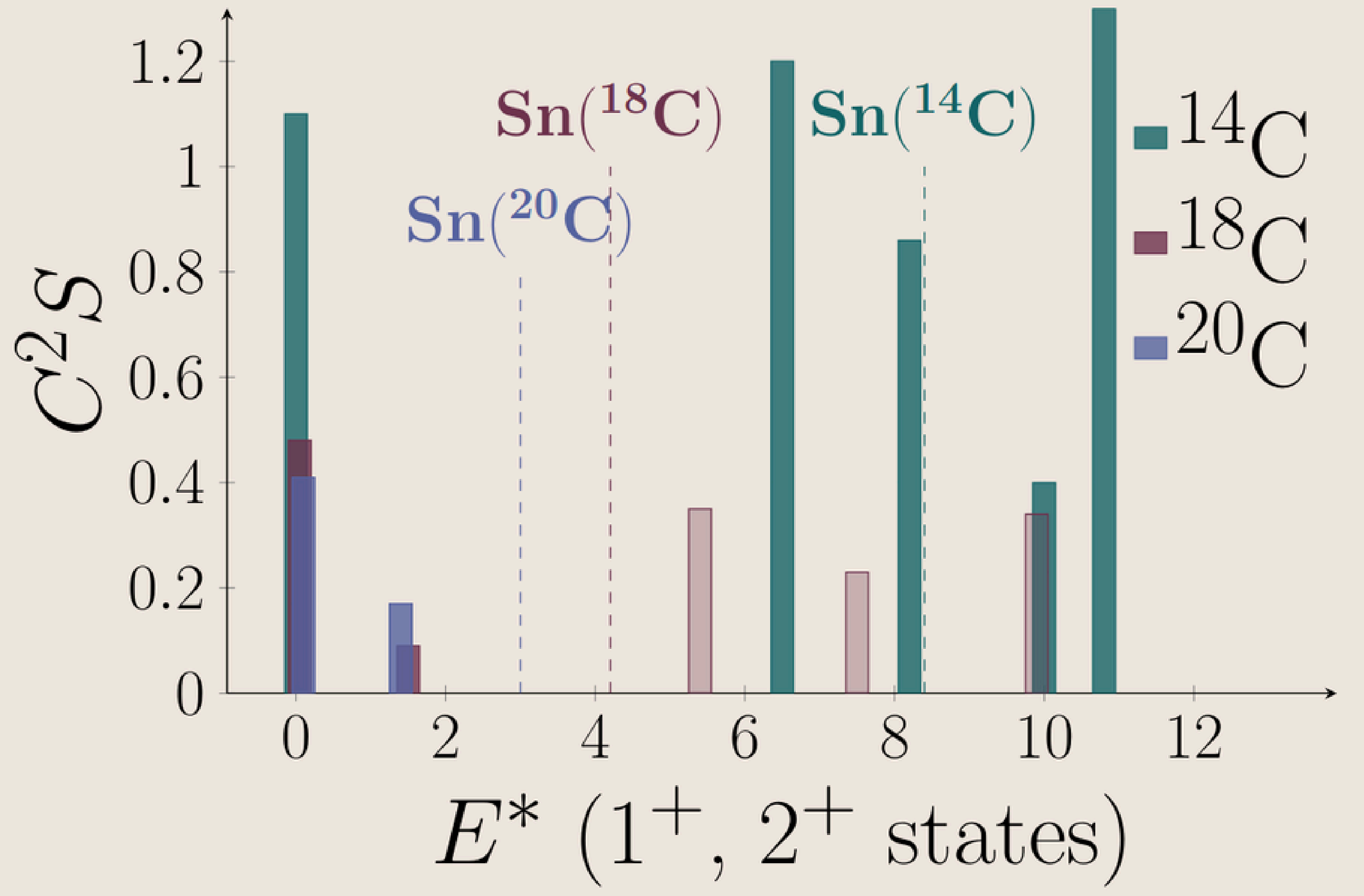

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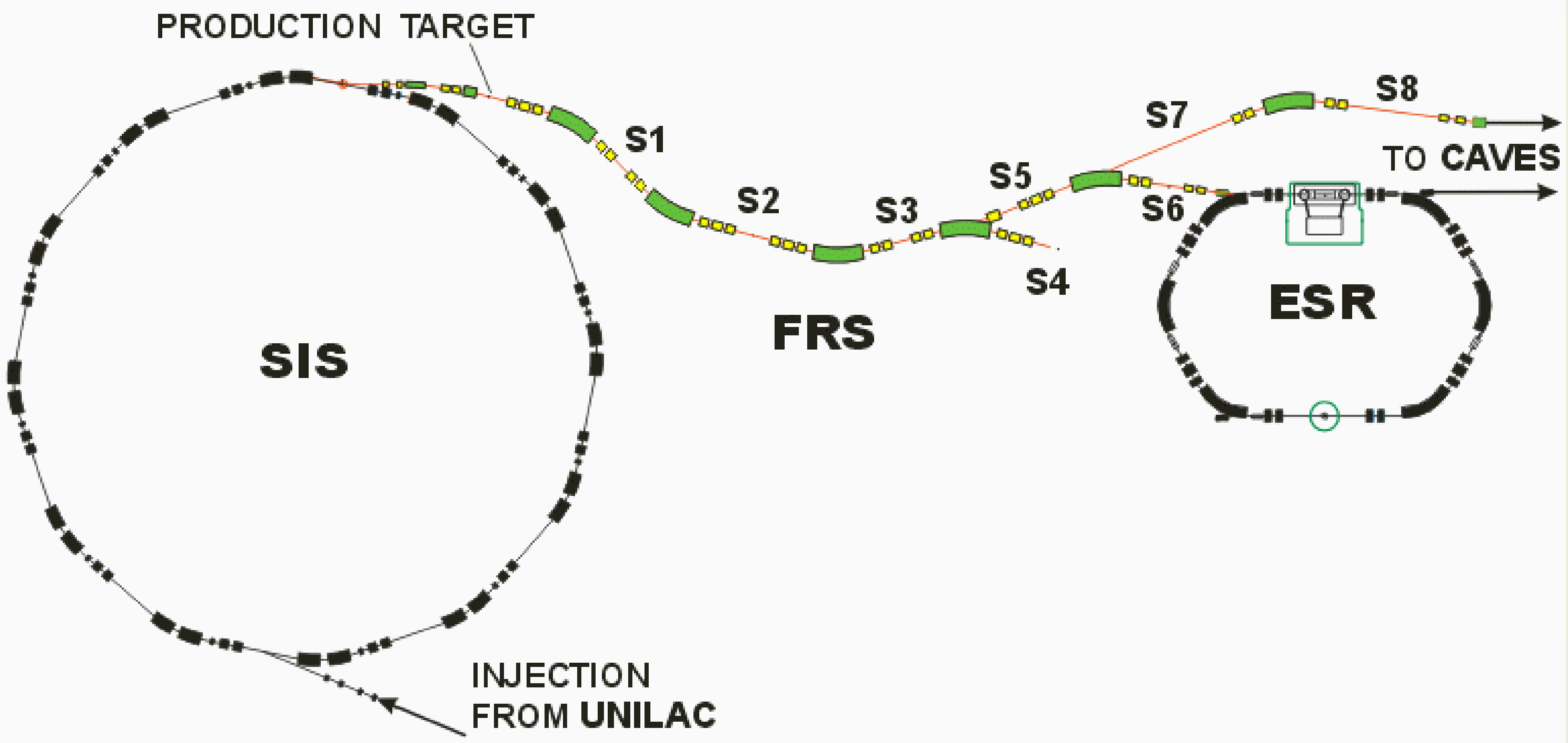
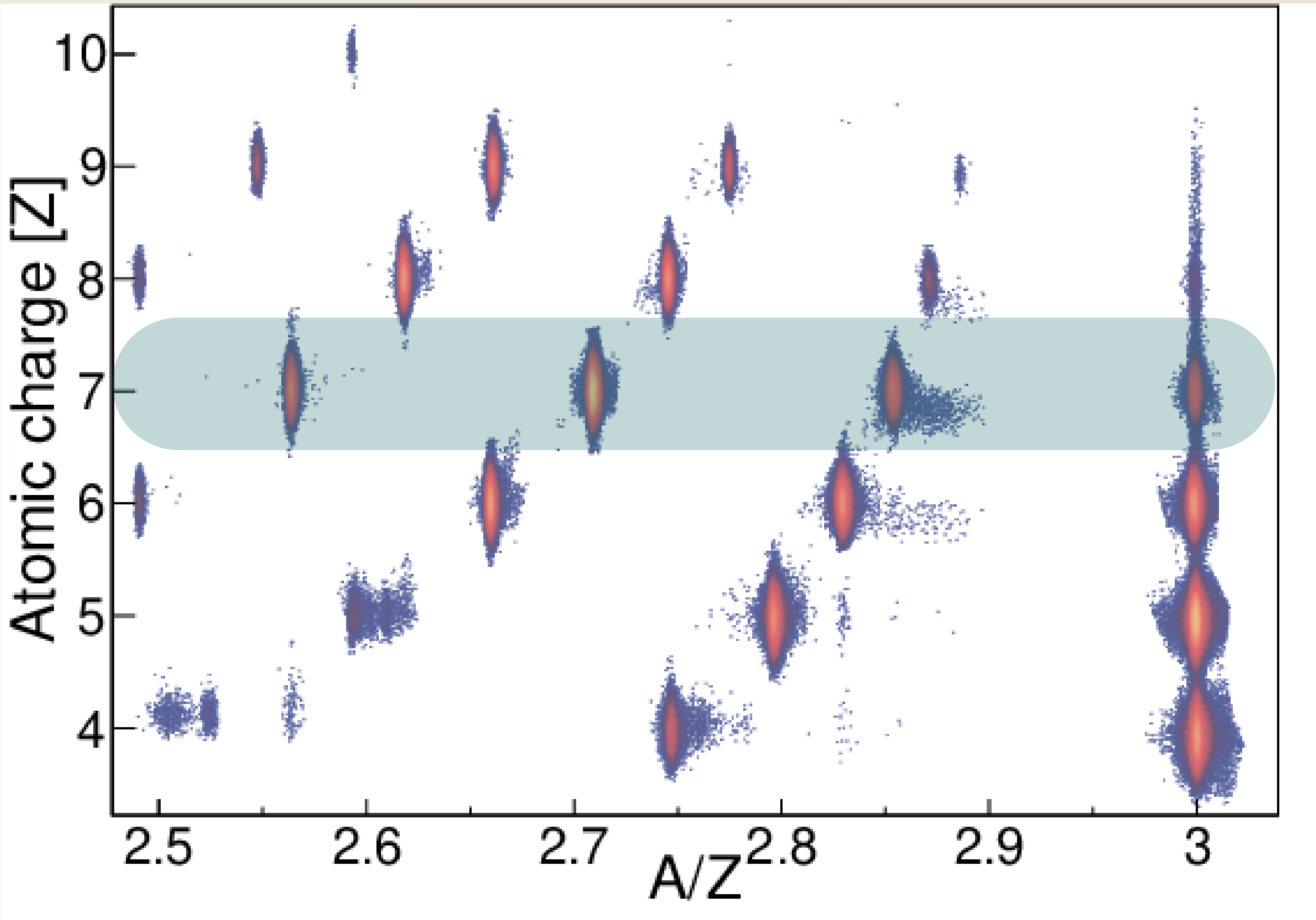
extend the work for 1n decay

s509 experiment, R^3B at GSI

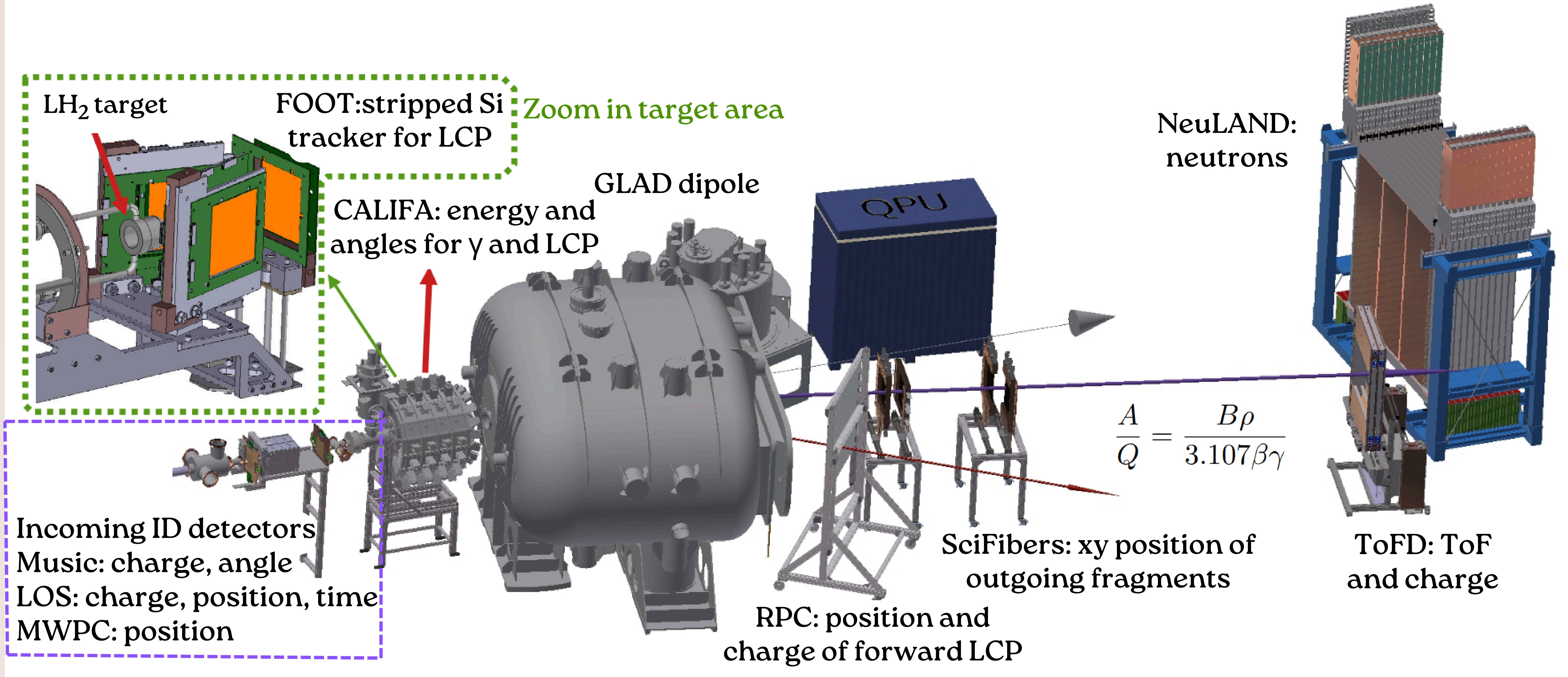


^{40}Ar primary beam 600 MeV/u
Be target (4g/cm^2) for secondary beam 540 MeV/u



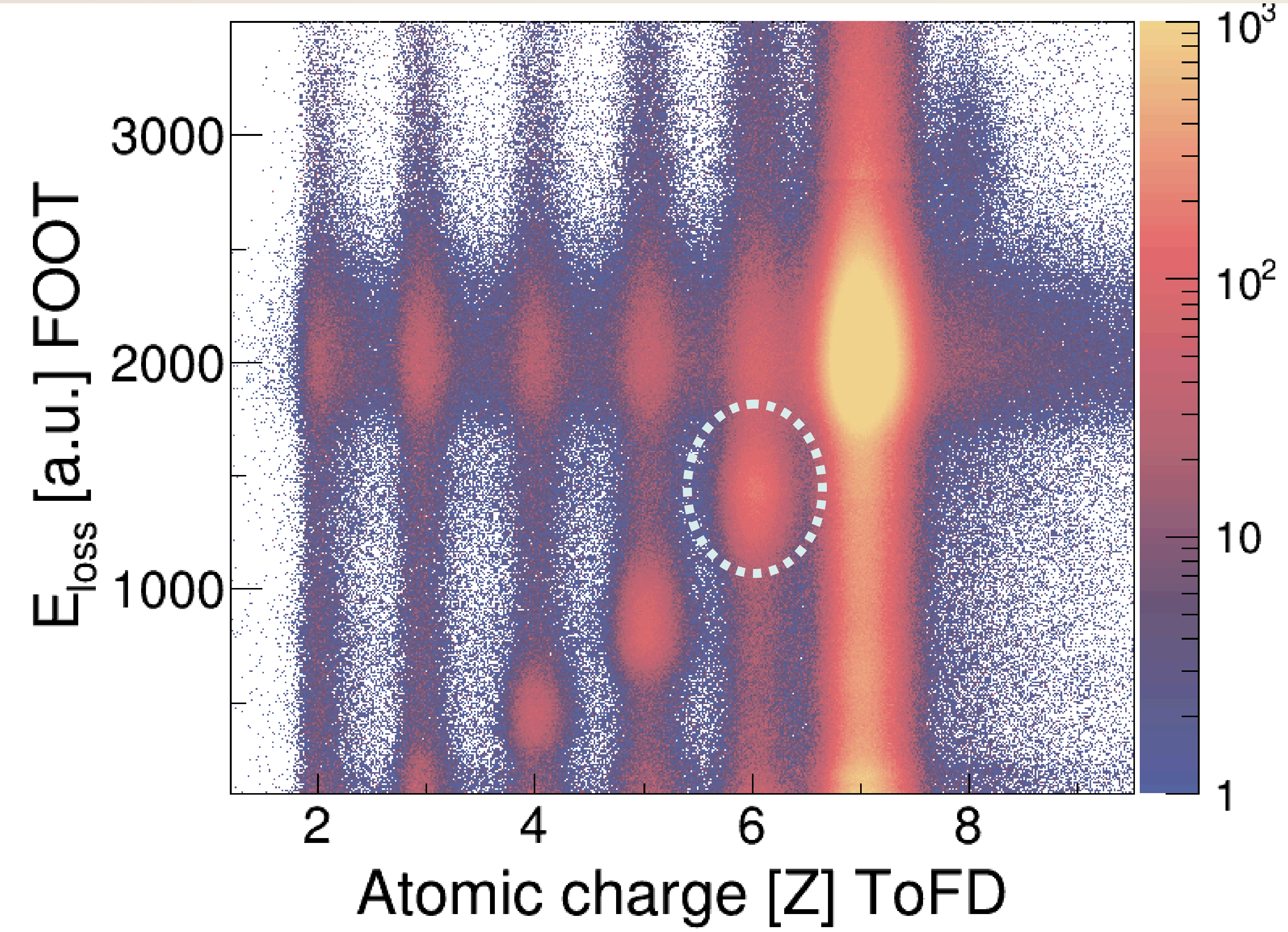
Incoming ID

The R^3B setup

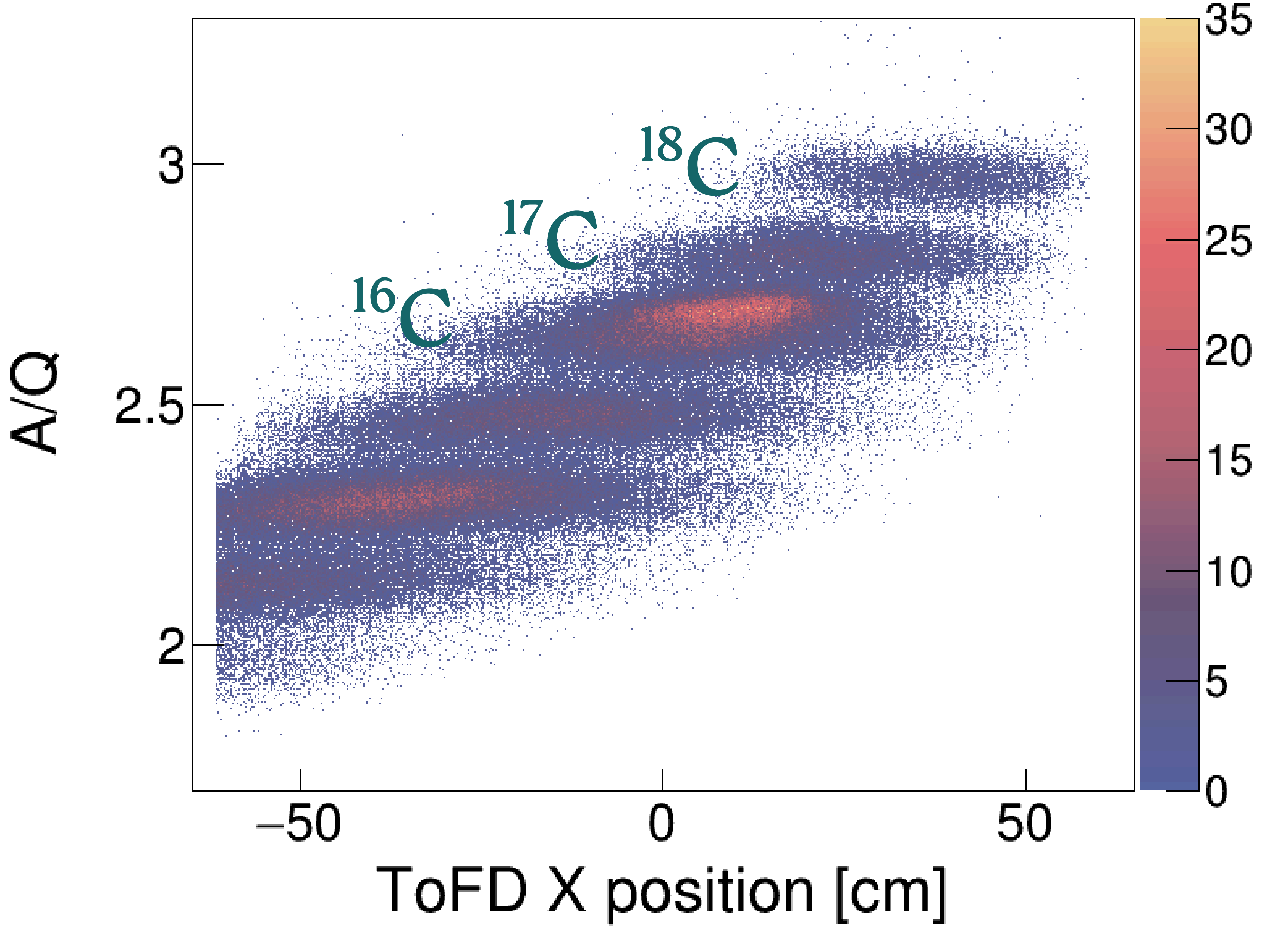


Fragment identification

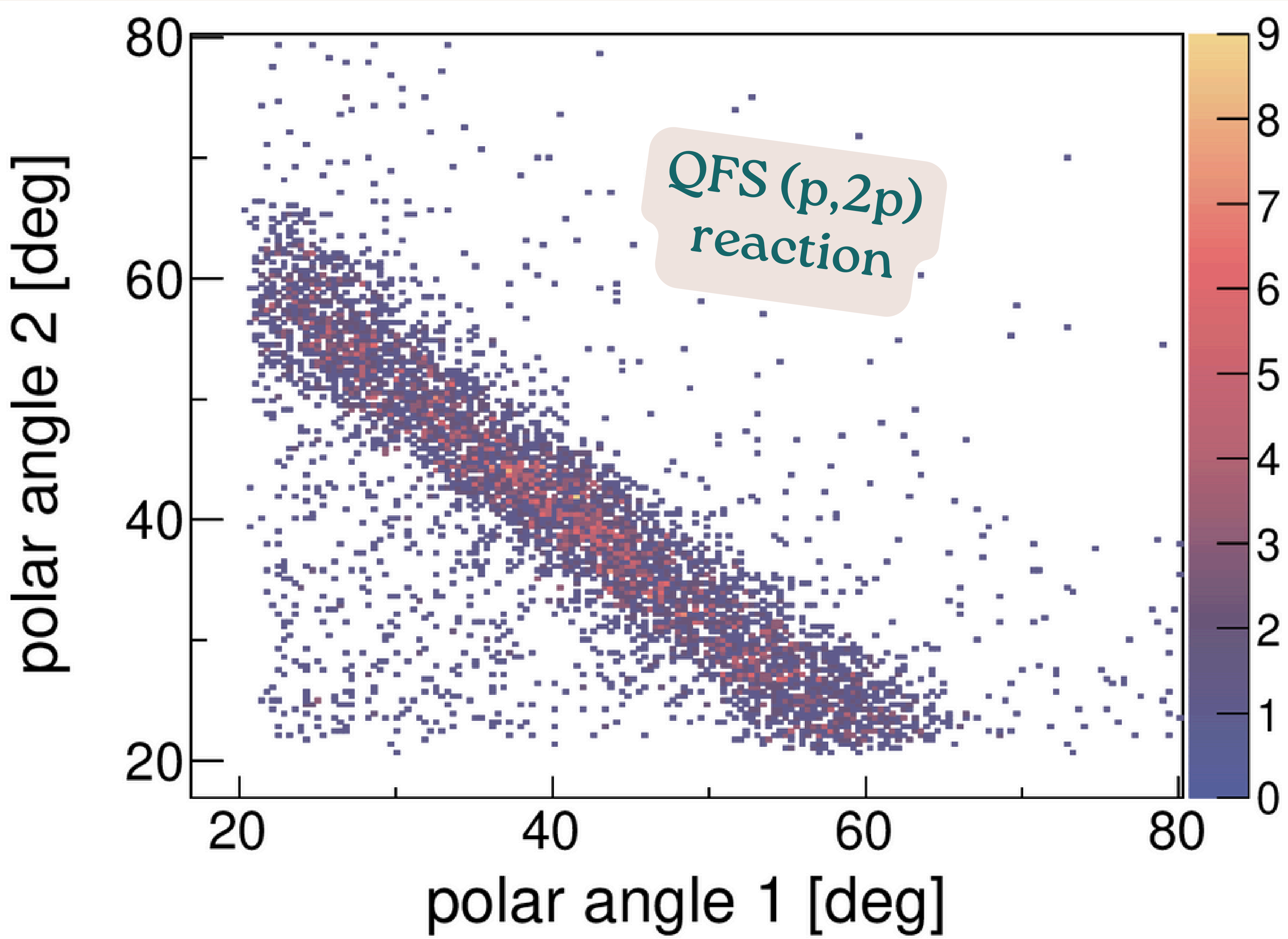
Charge correlation ^{19}N incoming

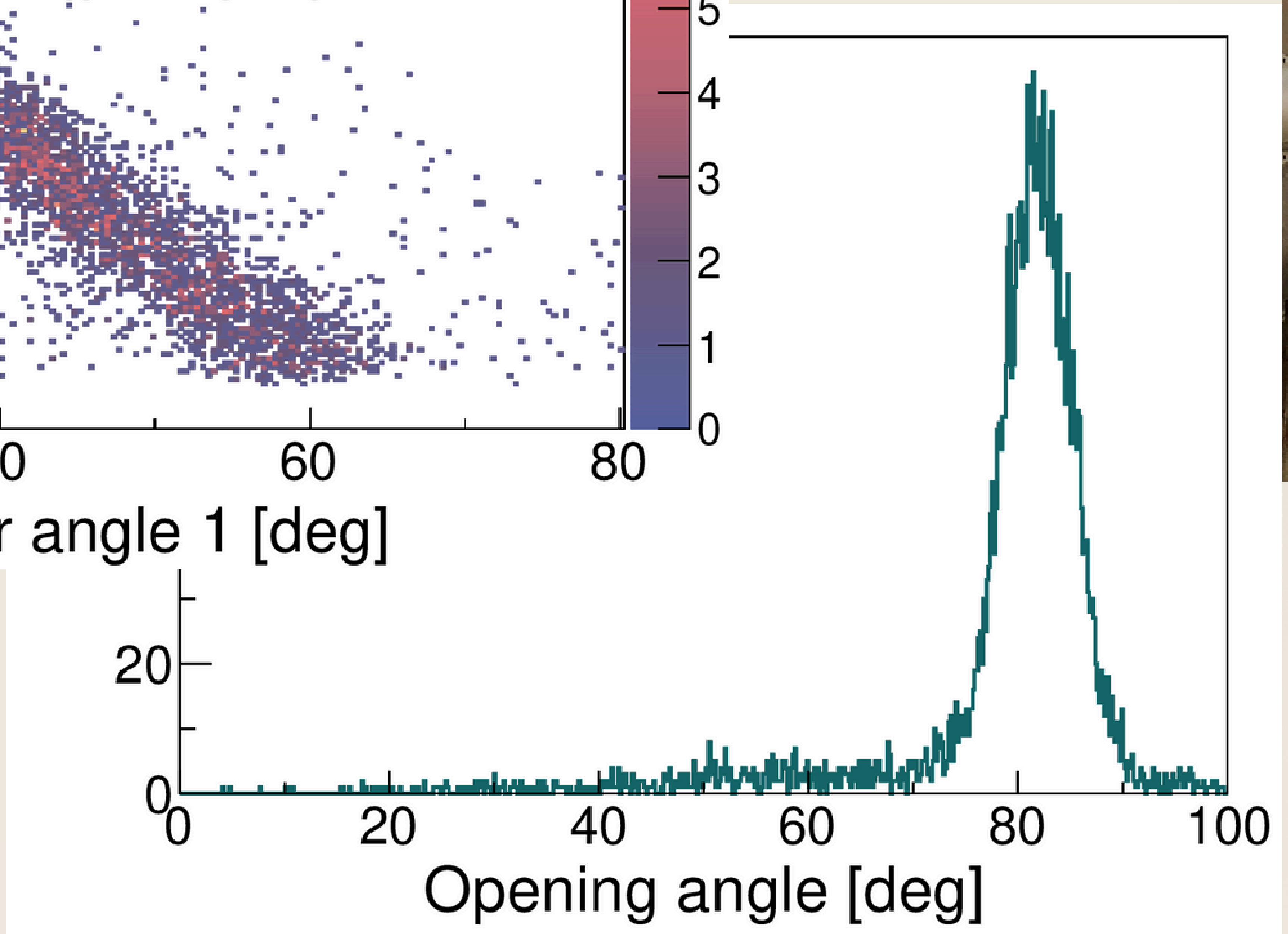


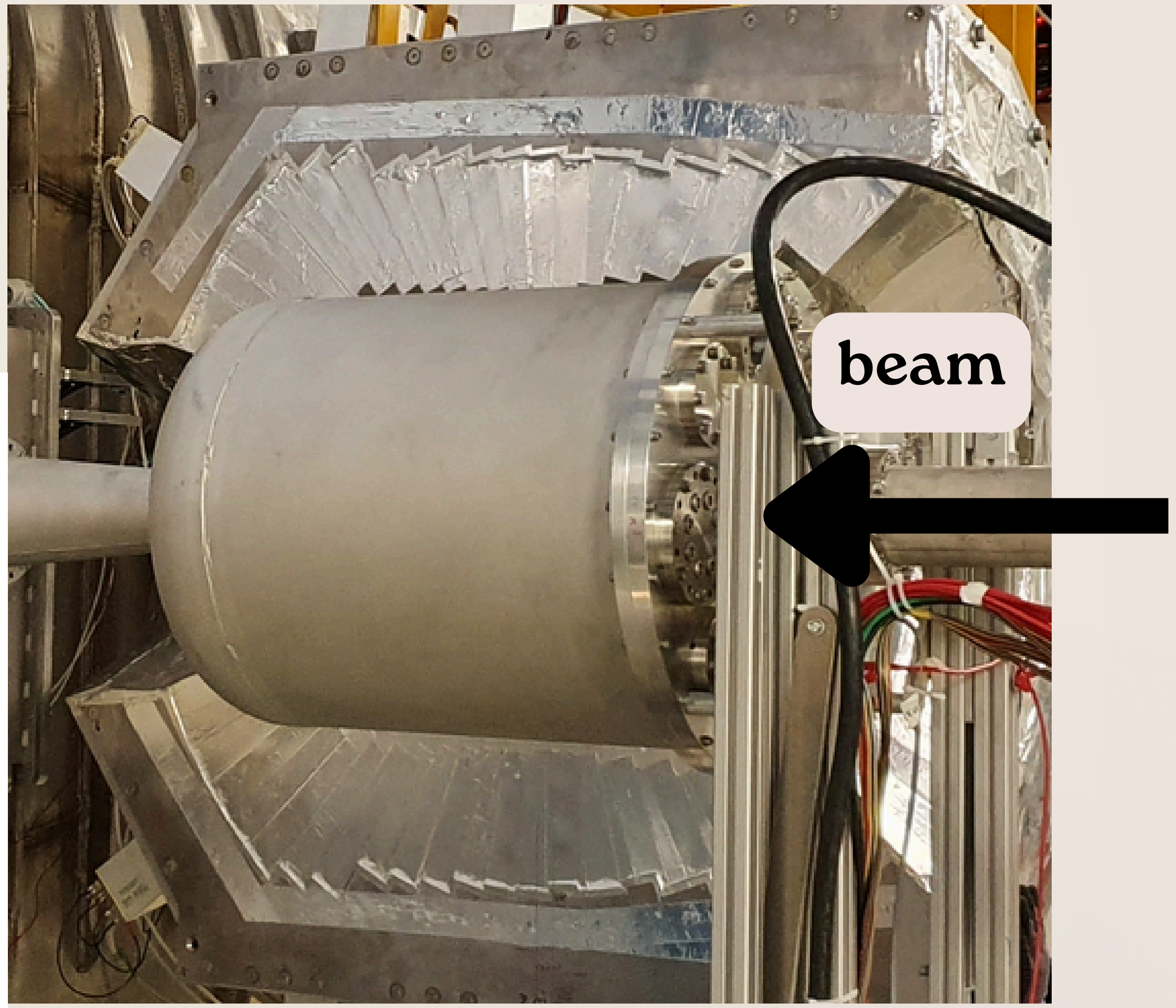
Outgoing fragments ^{19}N incoming + Z=6 cut



Califa detector



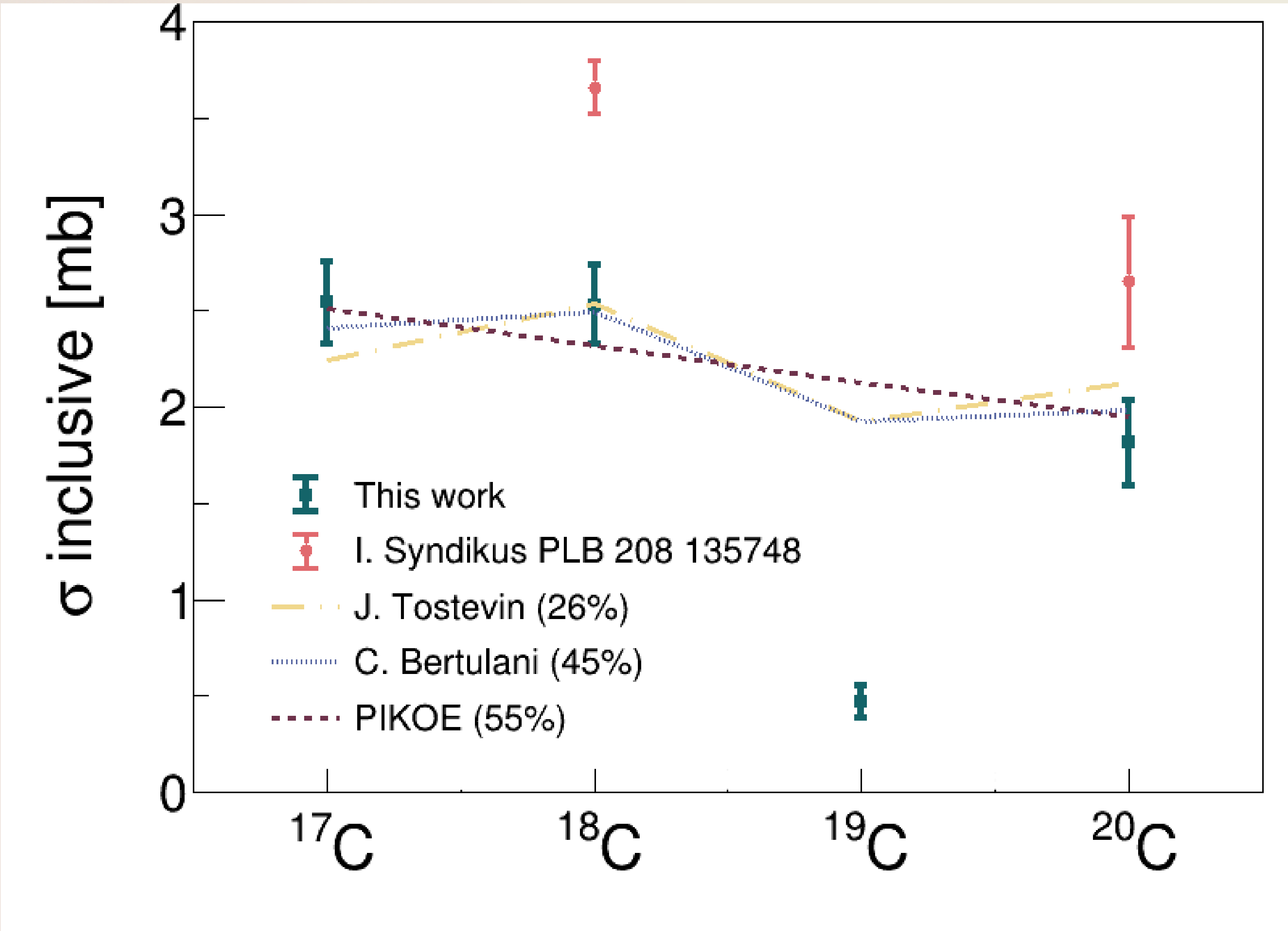




1504 CsI(Tl) crystals
θ 22º- 88º

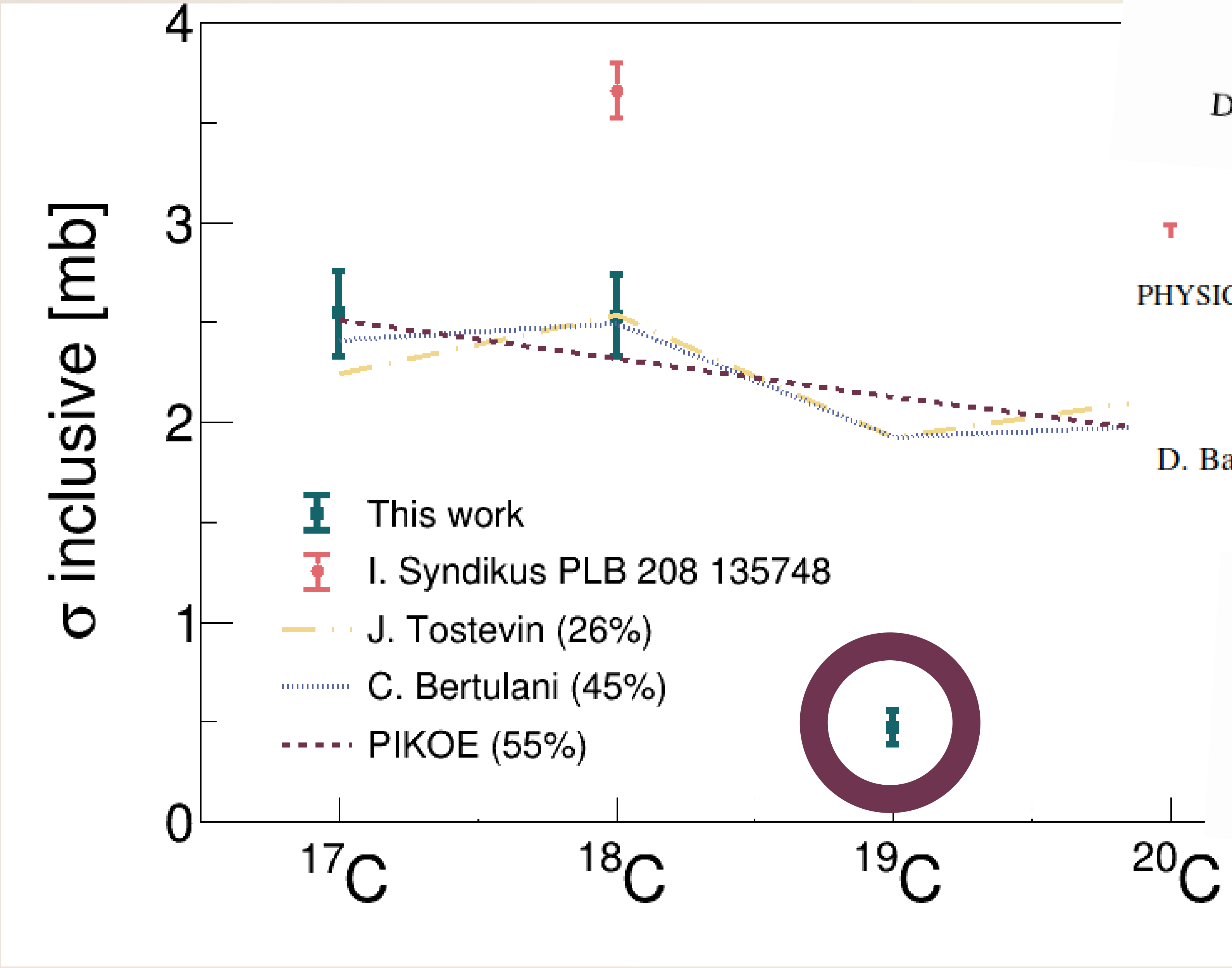
Inclusive cross sections N chain

$$\sigma_{incl} = \frac{N^{p2p}_{frag}}{N_{proj}} \cdot \frac{M_t}{N_A z \rho} \frac{1}{\varepsilon_{p2p} \cdot \varepsilon_{frag}}$$



Inclusive cross sections N chain

^{19}C halo nucleus



VOLUME 74, NUMBER 18 PHYSICAL REVIEW LETTERS 1 MAY 1995

One-Neutron Halo of ^{19}C

D. Bazin, B. A. Brown, J. Brown, M. Fauerbach, M. Hellström, S. E. Hirzebruch, J. H. Kelley, R. A. Kryger, D. J. Morrissey, R. Pfaff, C. F. Powell, B. M. Sherrill, and M. Thoennessen

PHYSICAL REVIEW C VOLUME 57, NUMBER 5

Probing the halo structure of ^{19,17,15}C and ^{14}B

D. Bazin, W. Benenson, B. A. Brown, J. Brown,* B. Davids, M. Fauerbach,† P. G. Hansen, P. Mantica, D. J. Morrissey, C. F. Powell, B. M. Sherrill, and M. Steiner

National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, Michigan 48824

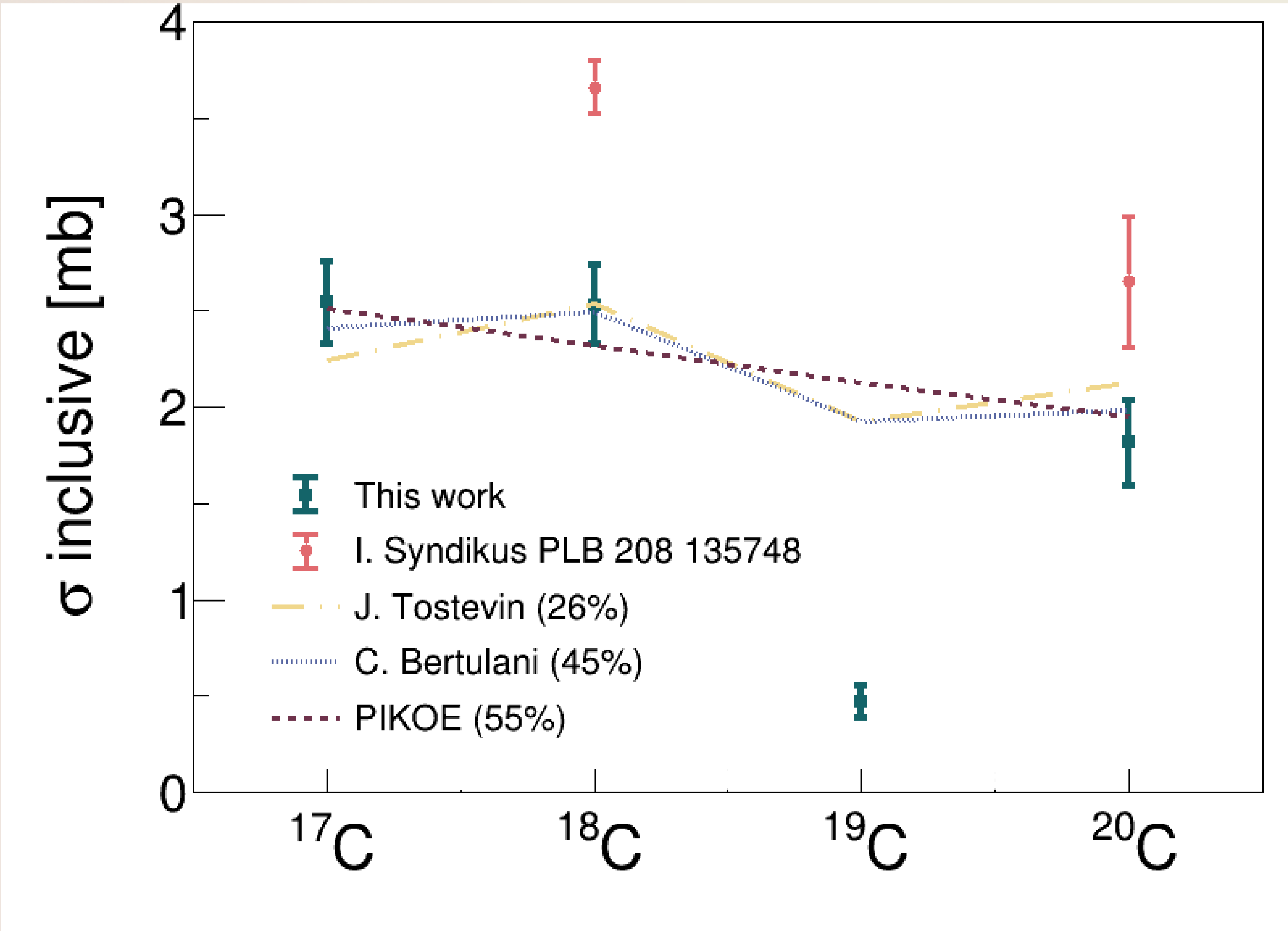
VOLUME 83, NUMBER 6 PHYSICAL REVIEW LETTERS 9 AUGUST 1999

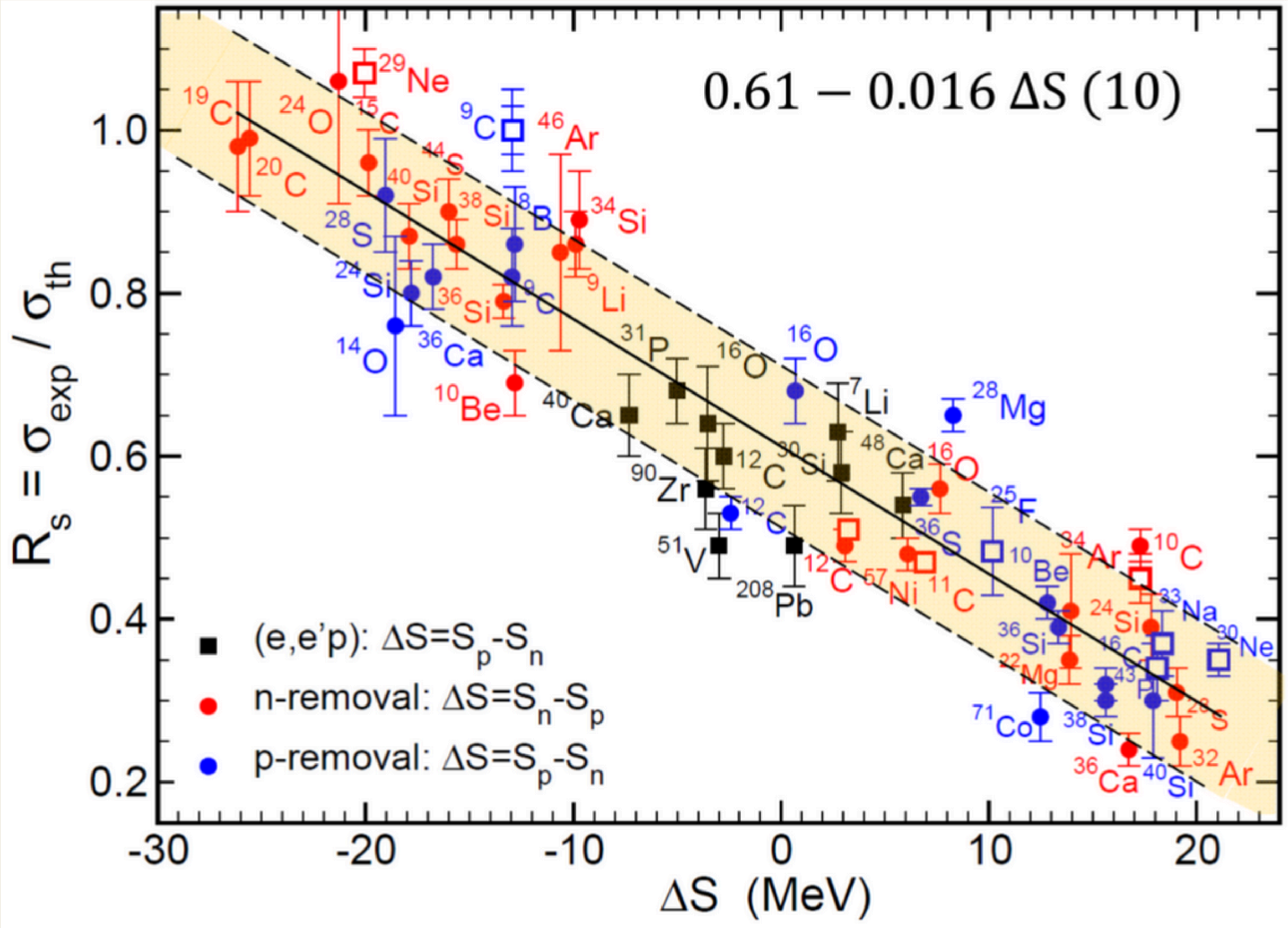
Coulomb Dissociation of ^{19}C and its Halo Structure

T. Nakamura,[1,*] N. Fukuda,[1] T. Kobayashi,[2] N. Aoi,[1] H. Iwasaki,[1] T. Kubo,[3] A. Mengoni,[3,†] M. Notani,[3] H. Otsu,[2] H. Sakurai,[3] S. Shimoura,[4] T. Teranishi,[3] Y. X. Watanabe,[1] K. Yoneda,[1] and M. Ishihara[1,3]

Inclusive cross sections N chain

Expected quenching





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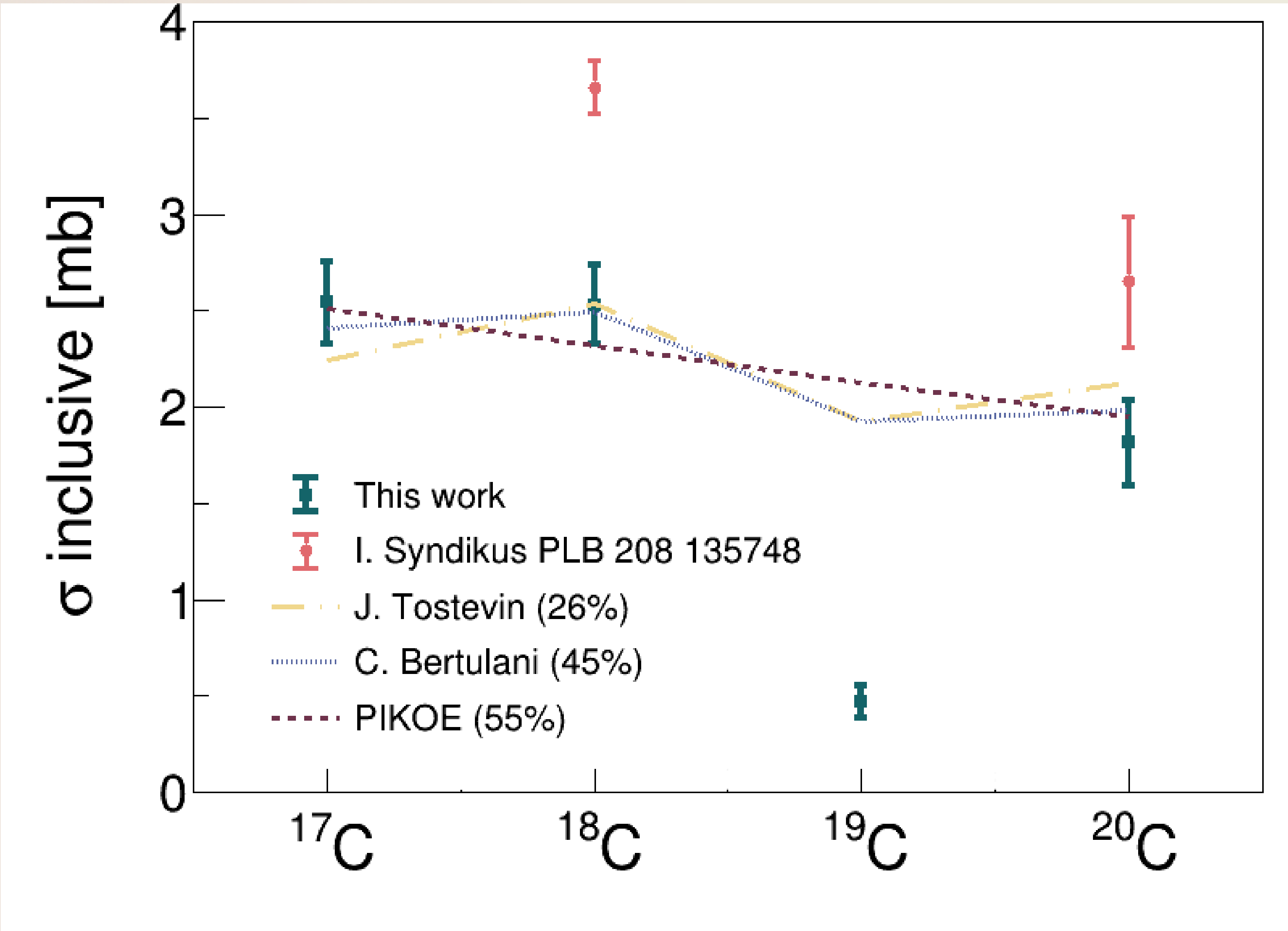
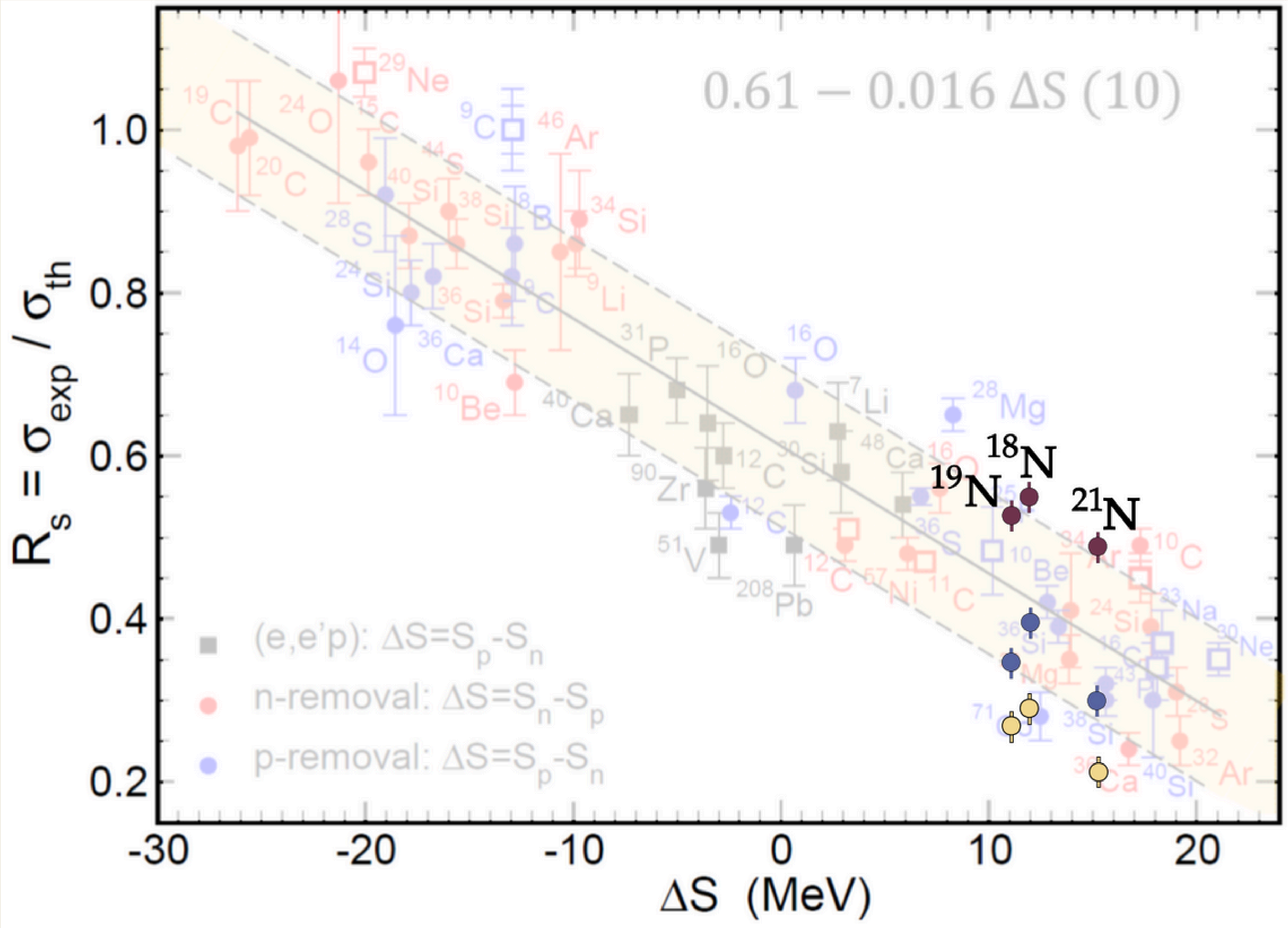
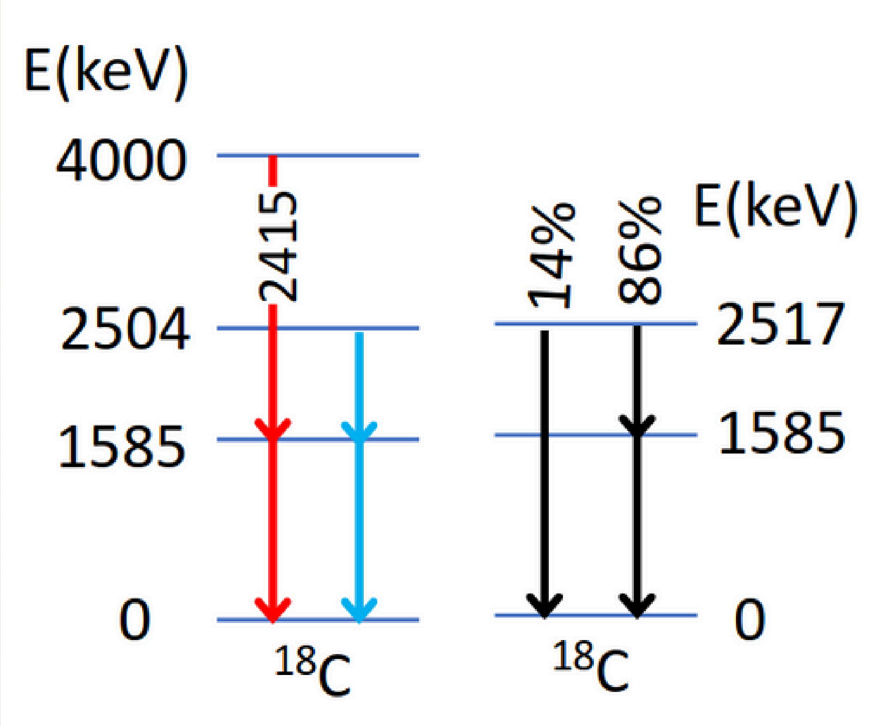
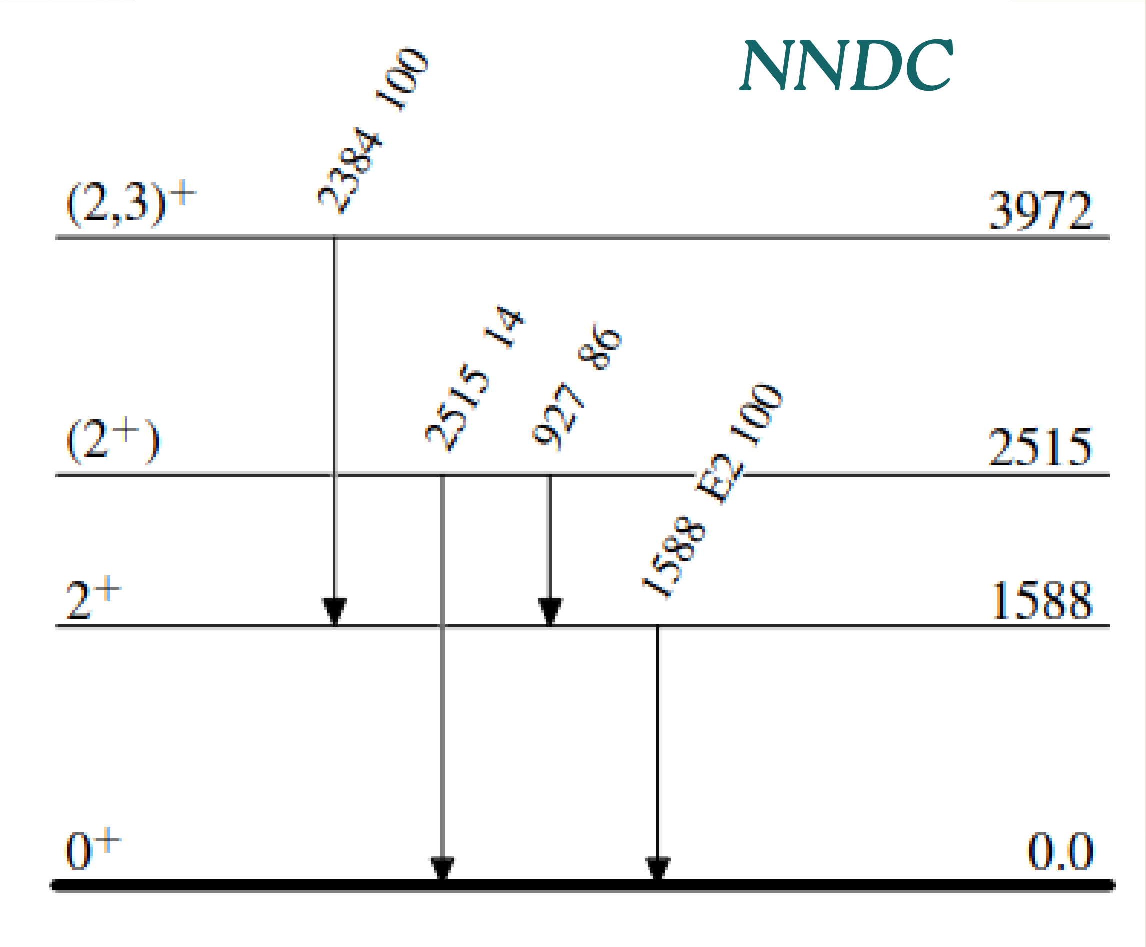


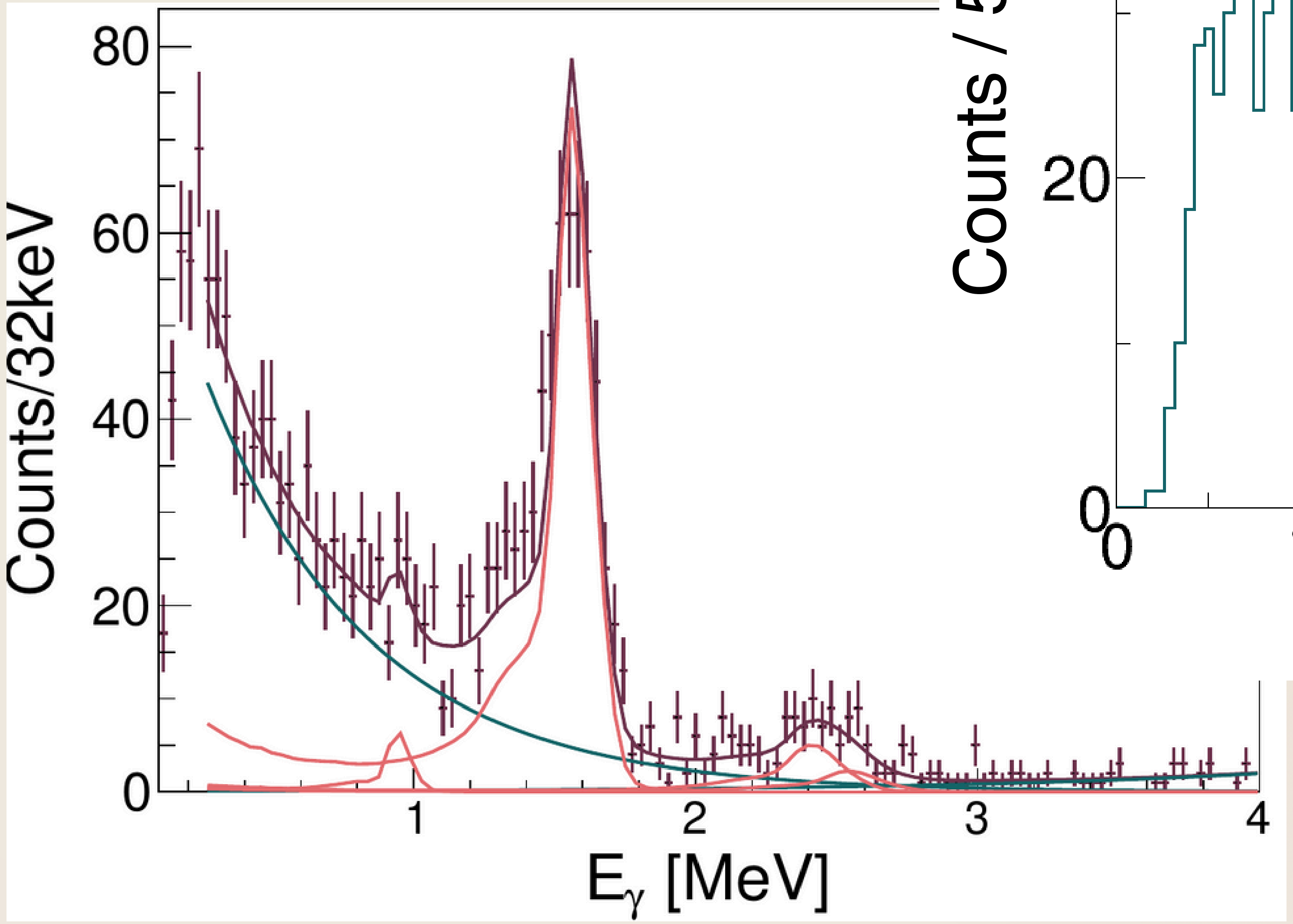


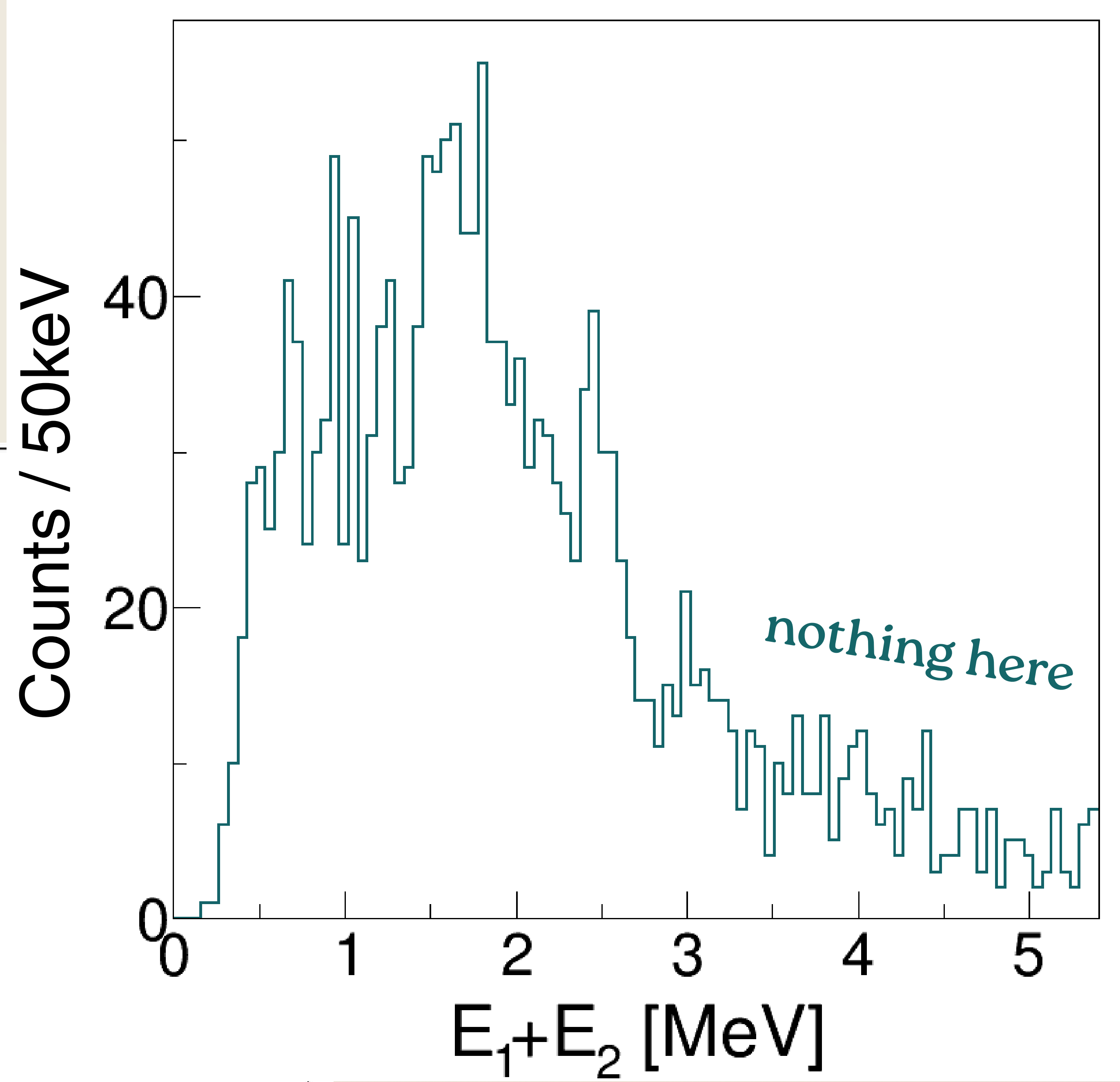
$^{19}N(p,2p)^{18}C$ bound



populated levels?







$^{19}N(p,2p)^{18}C$ bound

exclusive cross sections results, including γ-ray efficiency

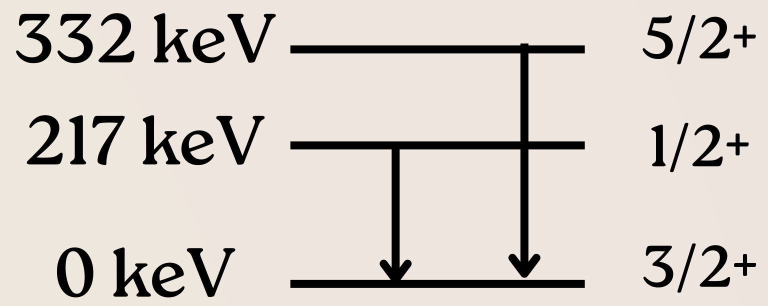
state		σ^{exl}_{p2p} [mb]			
E^* [MeV]	J^π	This work	I. Syndikus	$\sigma^{theo}_{s.p.}$	σ^{theo}_{excl}
0	0^+	2.04(21)	2.53(15)	5.267	4.086
1.59	2^+	0.388(36)	0.450(70)	5.193	0.800
2.51	2^+	0.099(17)	-	5.018	0.816

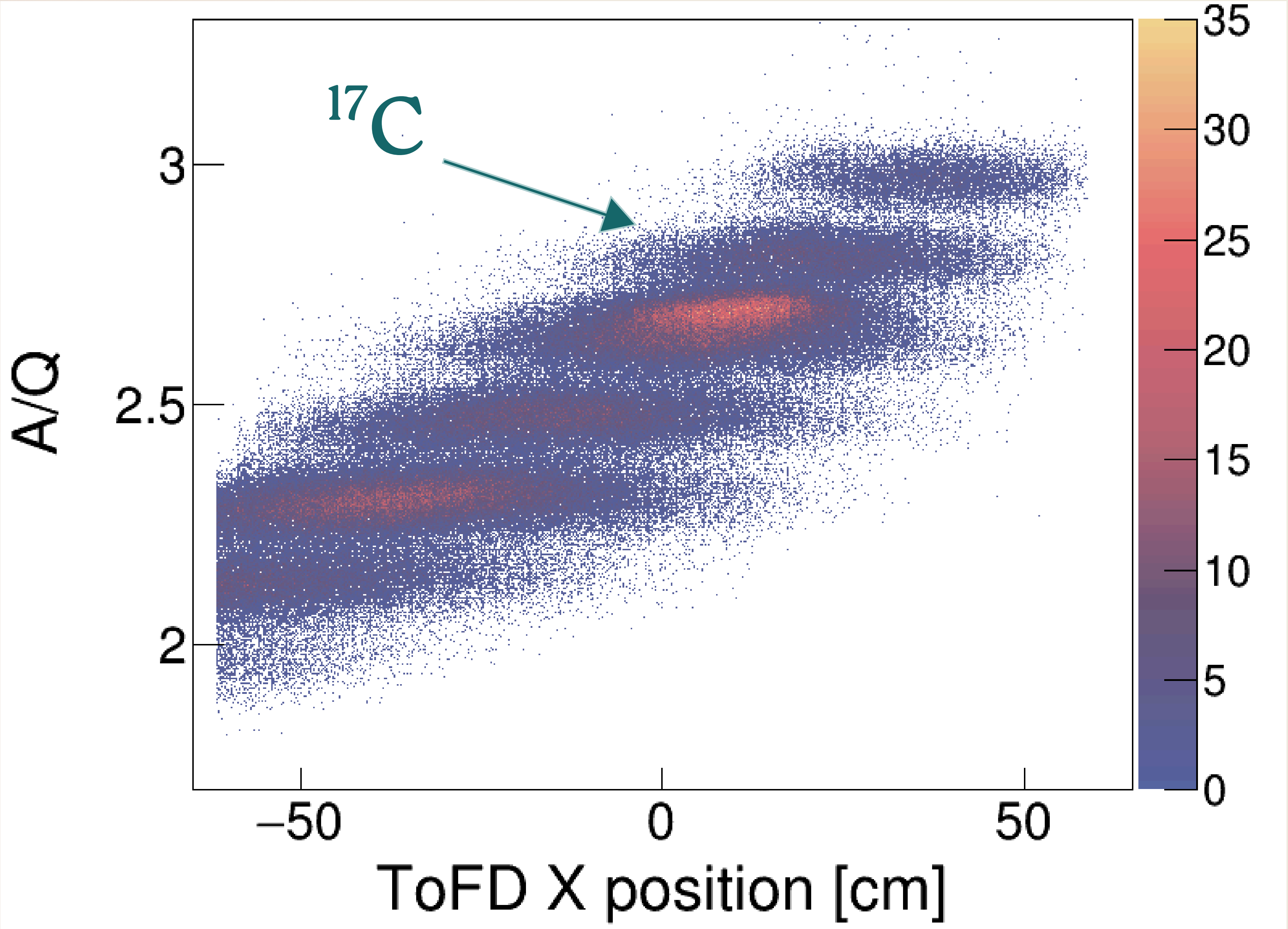
C^2S from WBT int.
A. Brown courtesy

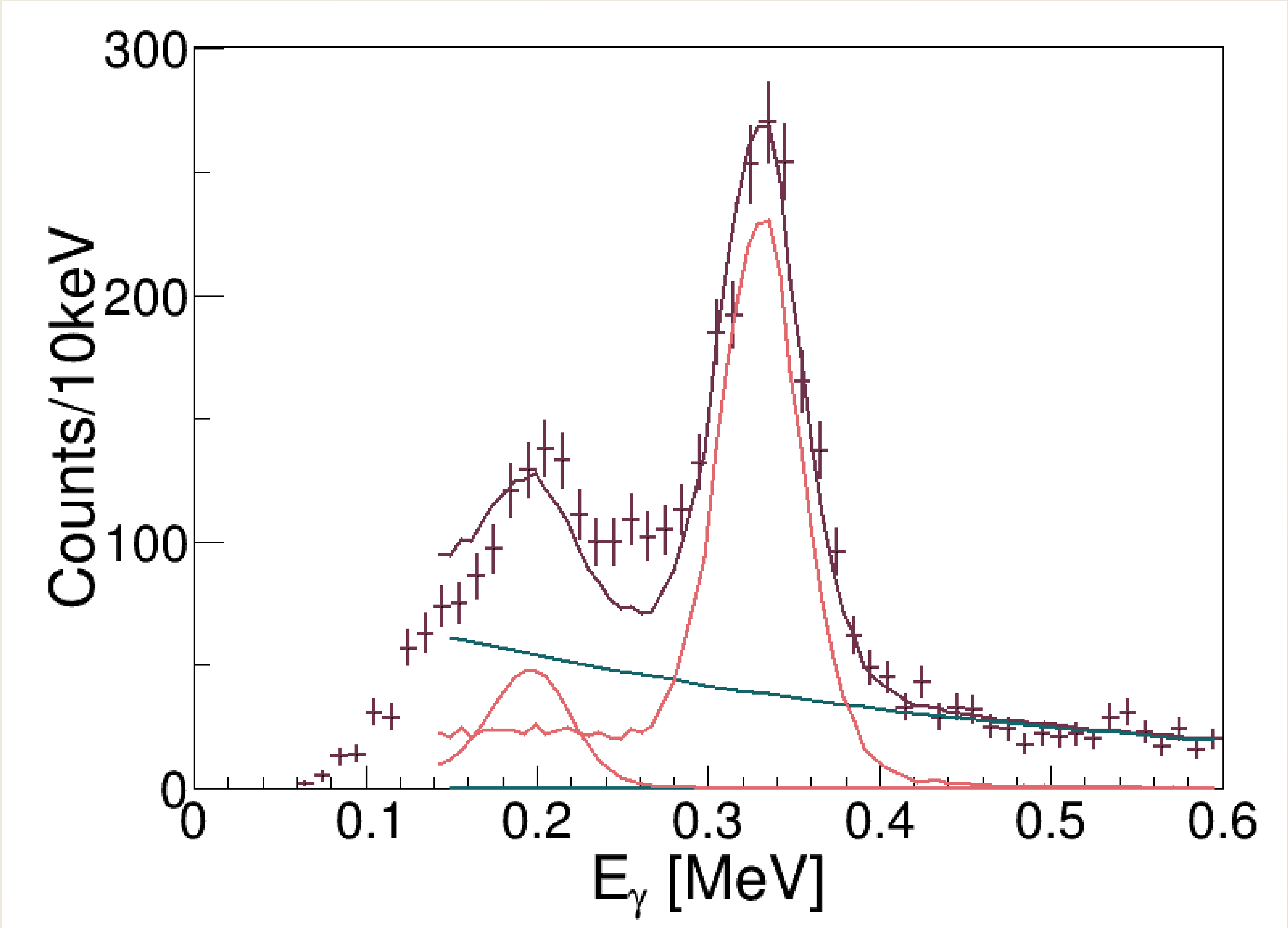
$C^2S(2_1+)/C^2S(0+) = 19.1\ (22)\ \%$

18.75 % (I. Syndikus)
PLB 809 135748

$^{19}N(p,2p)^{18}C^{*} \rightarrow ^{17}C+1n$







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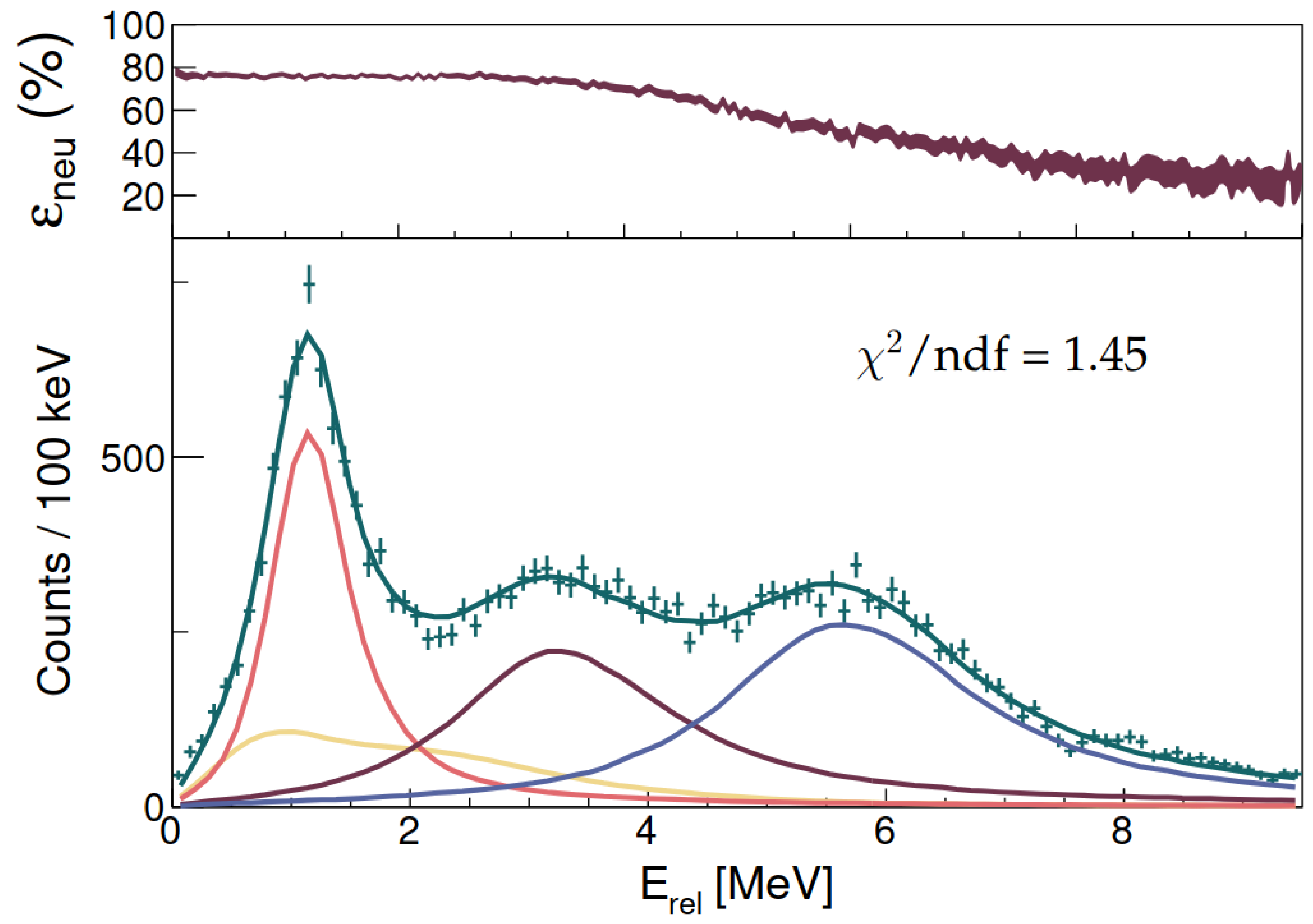
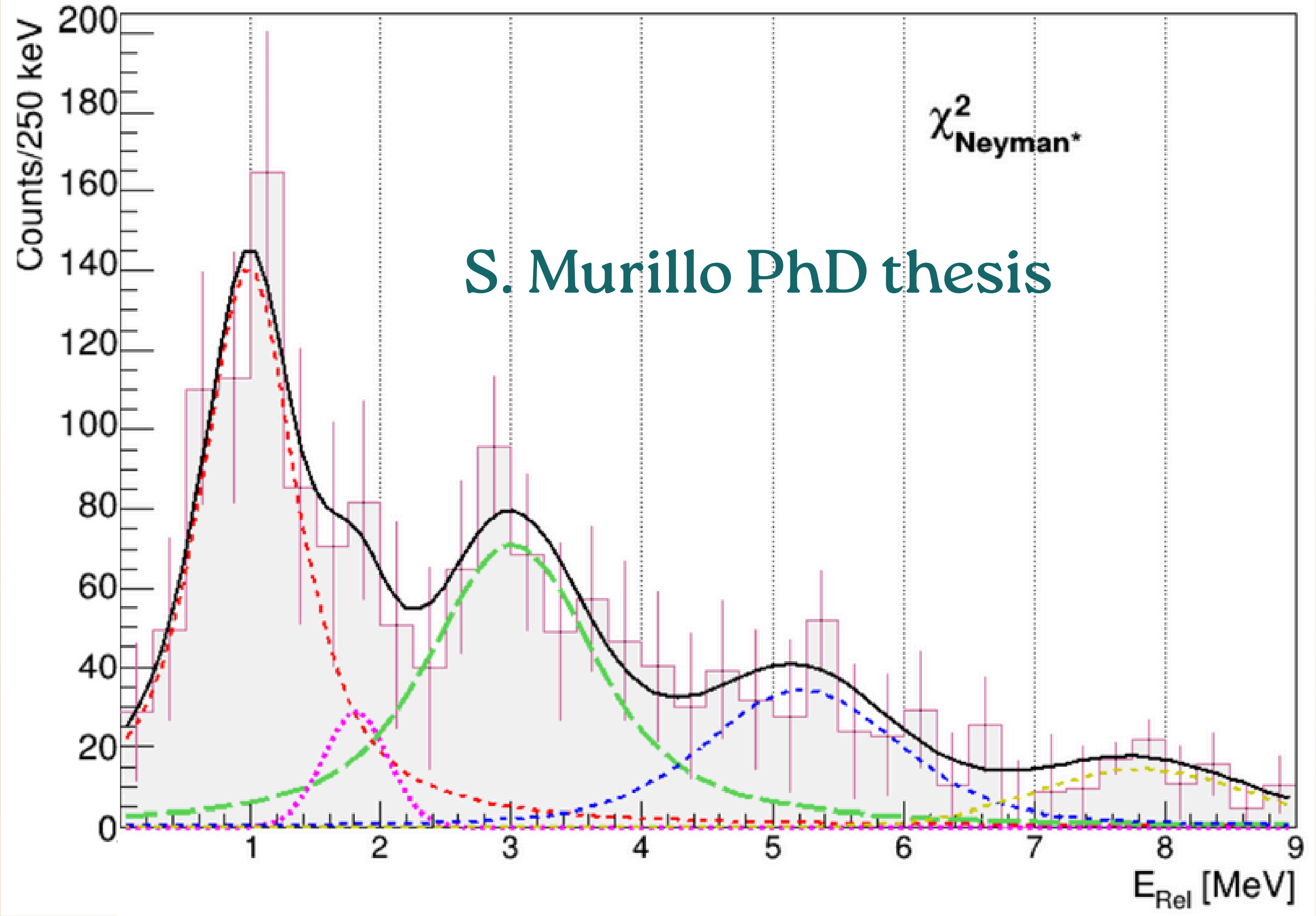


	E^* [MeV]	E_{rel} [MeV]	Γ [MeV]	σ^{exl}_{p2p+1n} [mb]
Res 1	5.305(15)	1.125(15)	0.356(63)	0.80(11)
Res 2	7.47(36)	3.324(36)	1.63(33)	1.01(18)
Res 3	9.90(29)	5.721(29)	1.78(40)	1.75(29)



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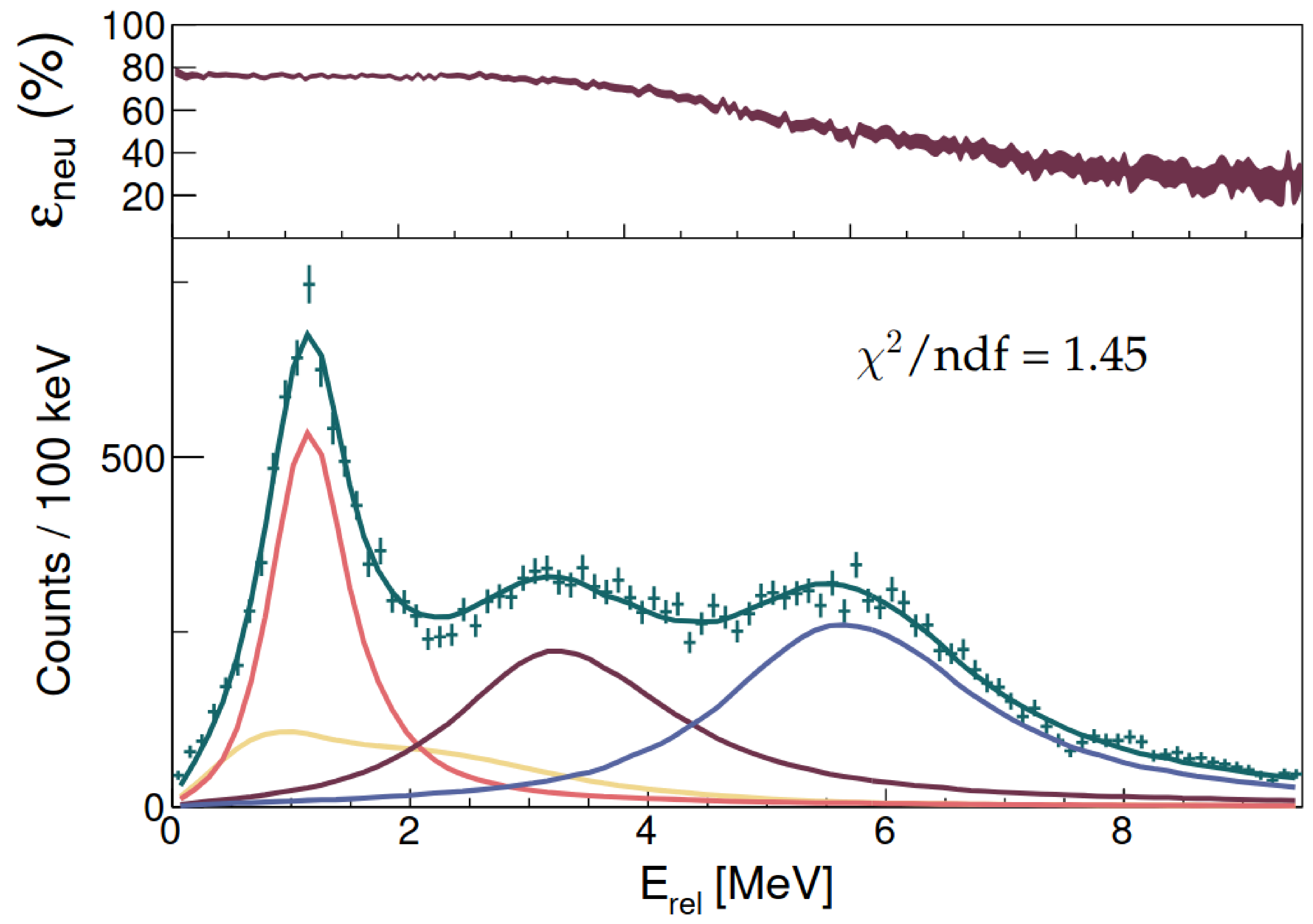

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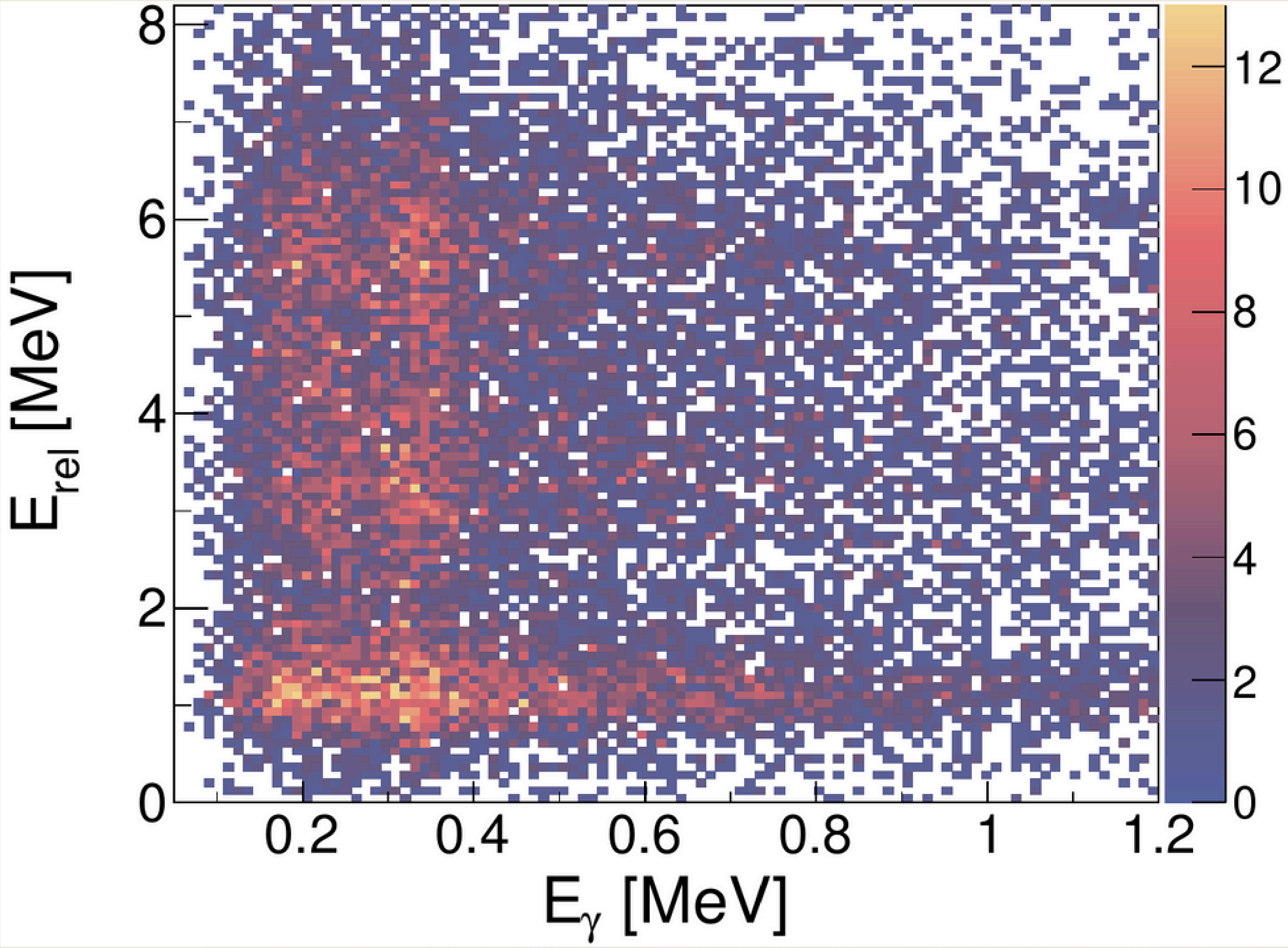

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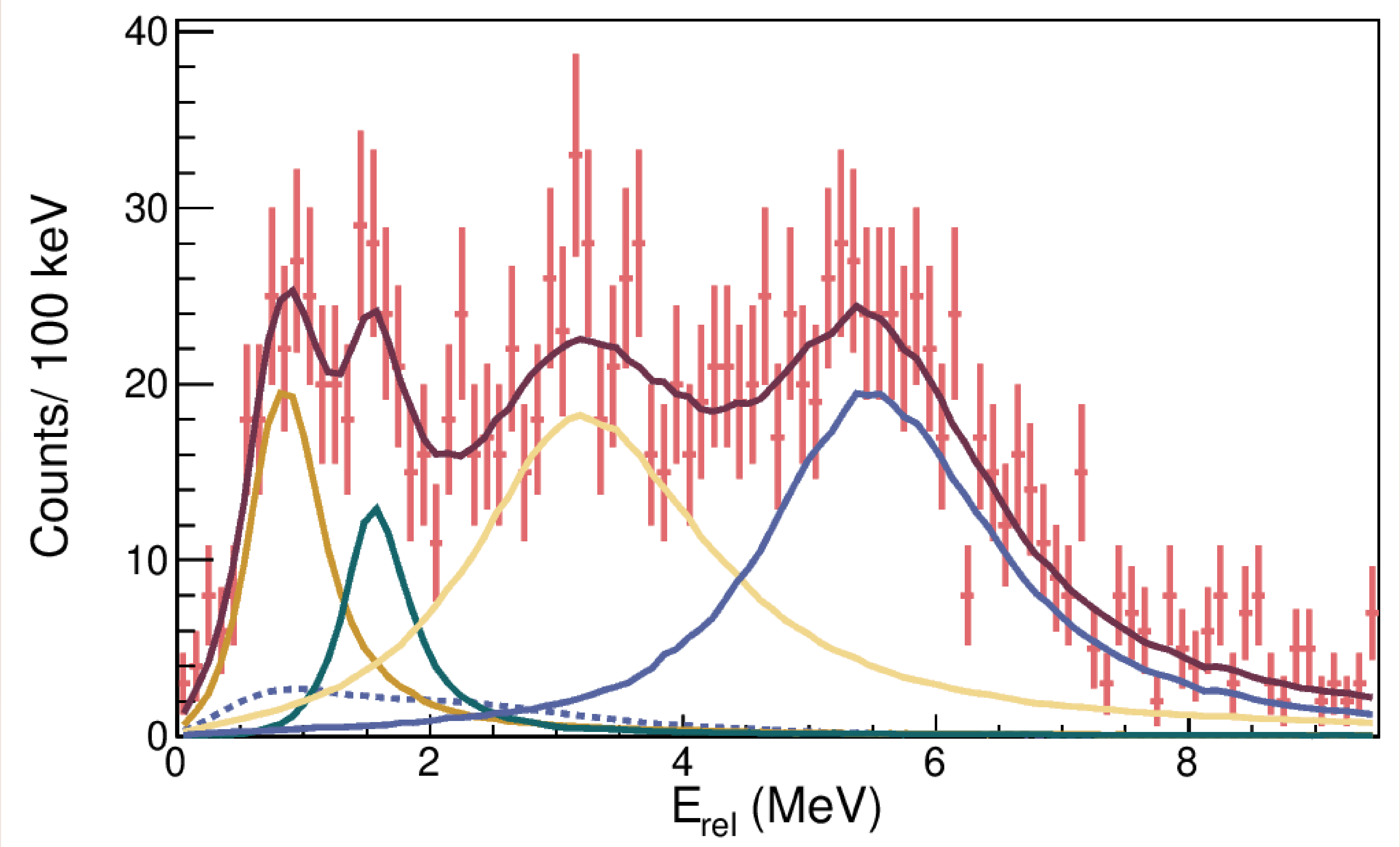

Gate on the 317 keV transition
+ γ-multiplicity < 3

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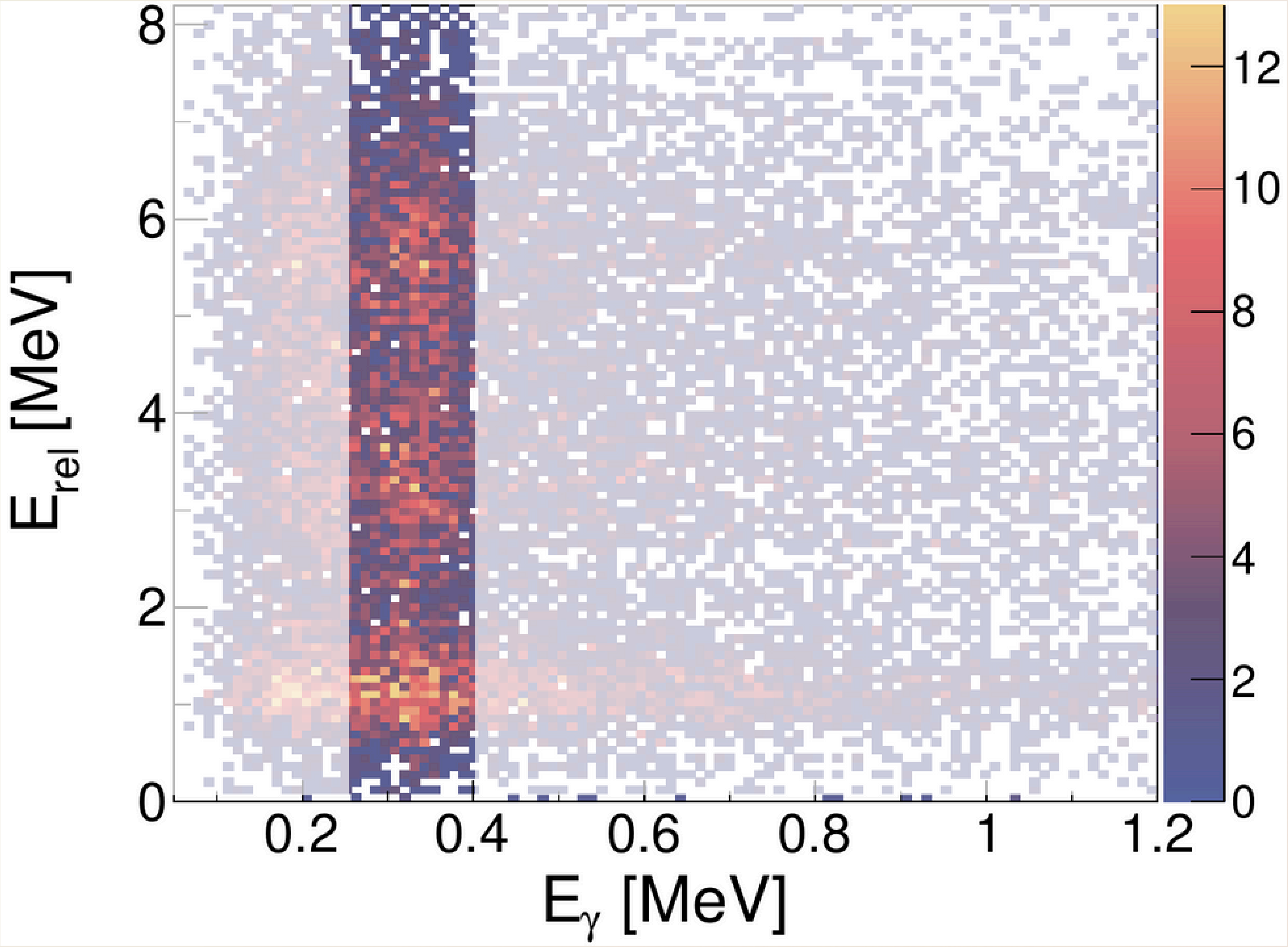
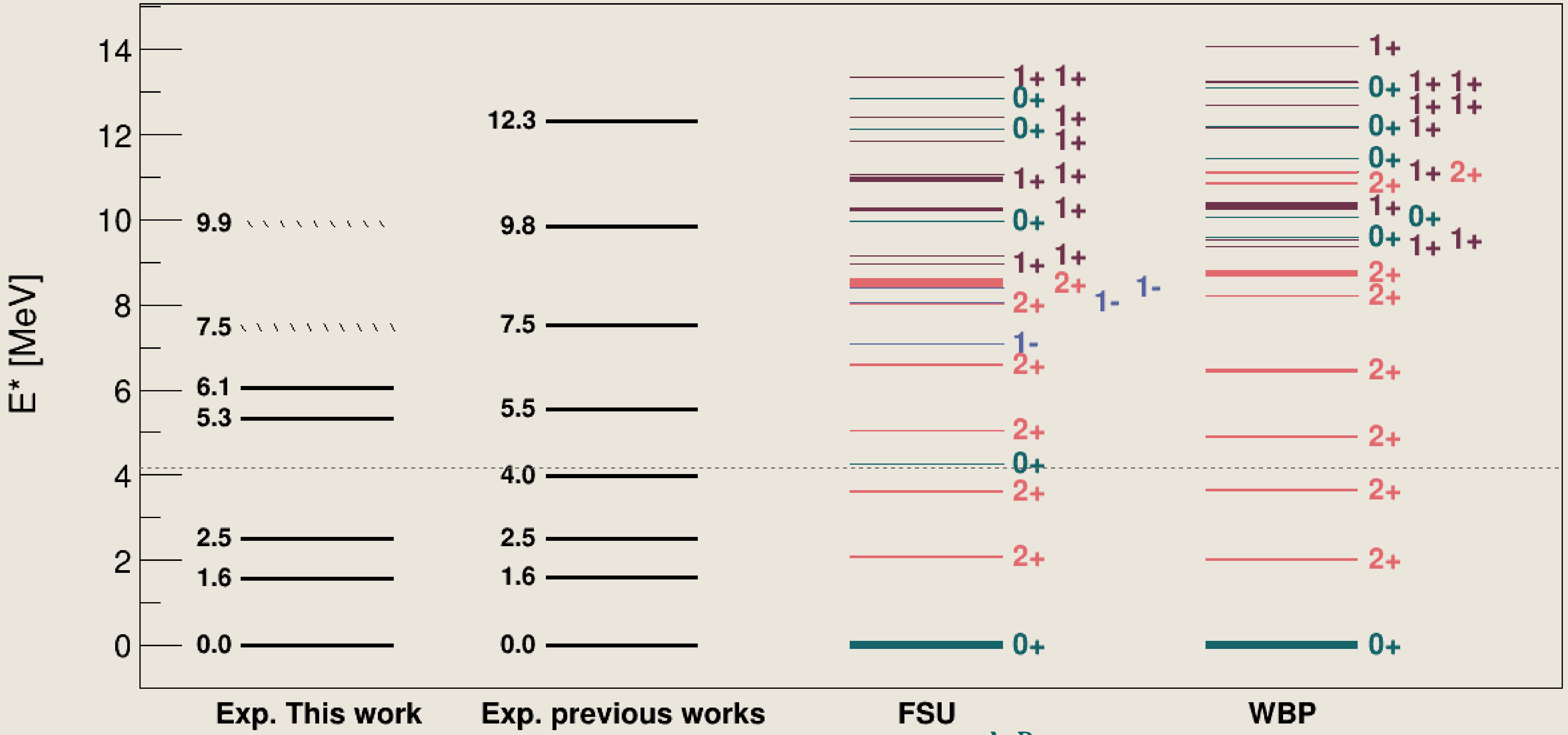


$^{19}N(p,2p)^{18}C$ bound + unbound



A. Brown courtesy

$^{19}N(p,2p)^{18}C$ bound + unbound

A. Brown courtesy

J^π	E^* [MeV]	σ^{excl}_{p2p} [mb]	E_{rel} [MeV]	Γ [MeV]	$\sigma^{th}_{s.p.}$ [mb]	C^2S^{exp}	$C^2S^{th}_{SM}$
0^+	0	2.04(21)	-	-	5.267	0.387(40)	0.775
2^+	1.59	0.388(36)	-	-	5.193	0.0747(70)	0.154
2^+	2.51	0.099(17)	-	-	5.018	0.00197(33)	0.162
(2^+)	5.305(15)	0.80(11)	1.125(15)	0.356(63)	4.737	0.169(23)	0.106
(2^+)	6.068(42)	0.0256()	1.552(42)	0.193(84)	-	-	0.190
(2^+)	7.47(36)	1.01(18)	3.324(36)	1.63(33)	4.529	0.223(39)	1.198
(2^+)	9.90(29)	1.75(29)	5.721(29)	1.78(40)	4.229	0.414(68)	0.800

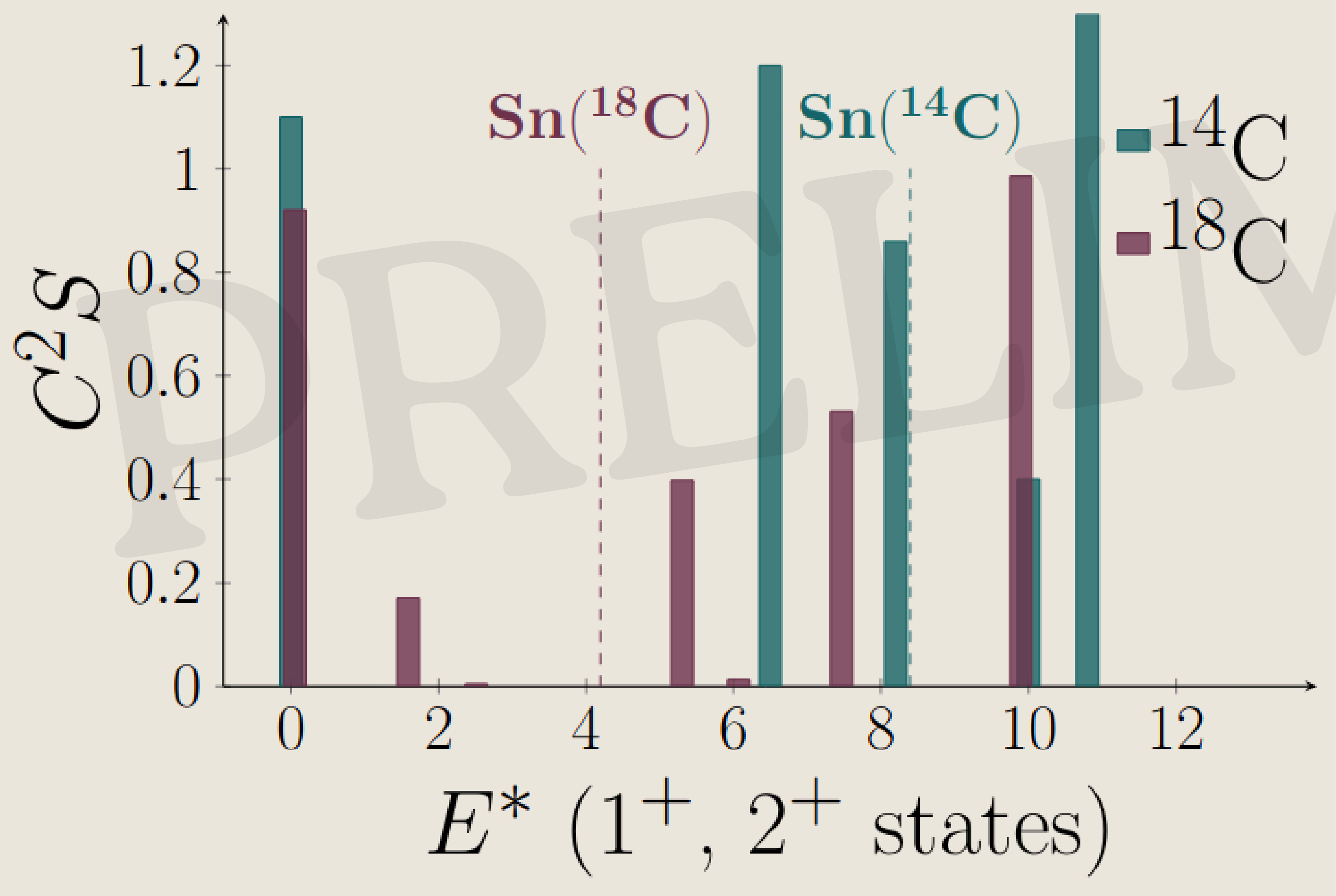
PRELIMINARY

Energy centroid of the 1+ and 2+ states

$$\langle E(J^\pi)\rangle = \frac{\sum_k (2J+1)\, C^2S_k^+(J^\pi)\cdot(E_k^+(J^\pi)-E_0) + \sum_{k'} C^2S_{k'}^-(J^\pi)\cdot(E_0-E_{k'}^-(J^\pi))}{\sum_k (2J+1)\, C^2S_k^+(J^\pi) + \sum_{k'} C^2S_{k'}^-(J^\pi)}$$

$^{19}N(p,2p)^{18}C$ bound + unbound

$$\langle E(J^\pi)\rangle = \frac{\sum_k (2J+1)\, C^2S_k^+(J^\pi)\cdot(E_k^+(J^\pi)-E_0) + \sum_{k'} C^2S_{k'}^-(J^\pi)\cdot(E_0-E_{k'}^-(J^\pi))}{\sum_k (2J+1)\, C^2S_k^+(J^\pi) + \sum_{k'} C^2S_{k'}^-(J^\pi)}$$



Energy centroid of the 1+ and 2+ states

$\langle E(1^+,2^+)\rangle(^{18}C) = 7.77$ MeV

$\langle E(1^+,2^+)\rangle(^{14}C) = 9.15$ MeV

$\Delta\langle E(1^+,2^+)\rangle = -1.38$ MeV

$^{19}N(p,2p)^{18}C$ bound + unbound

Estimation from TBME

$$\Delta V^{pn} = n_{d_{5/2}}\left(V^{pn}(p_{1/2}, d_{5/2}) - V^{pn}(p_{3/2}, d_{5/2})\right) + \\ + n_{s_{1/2}}\left(V^{pn}(p_{1/2}, s_{1/2}) - V^{pn}(p_{3/2}, s_{1/2})\right)$$

from momentum distributions

Energy centroid of the 1^+ and 2^+ states

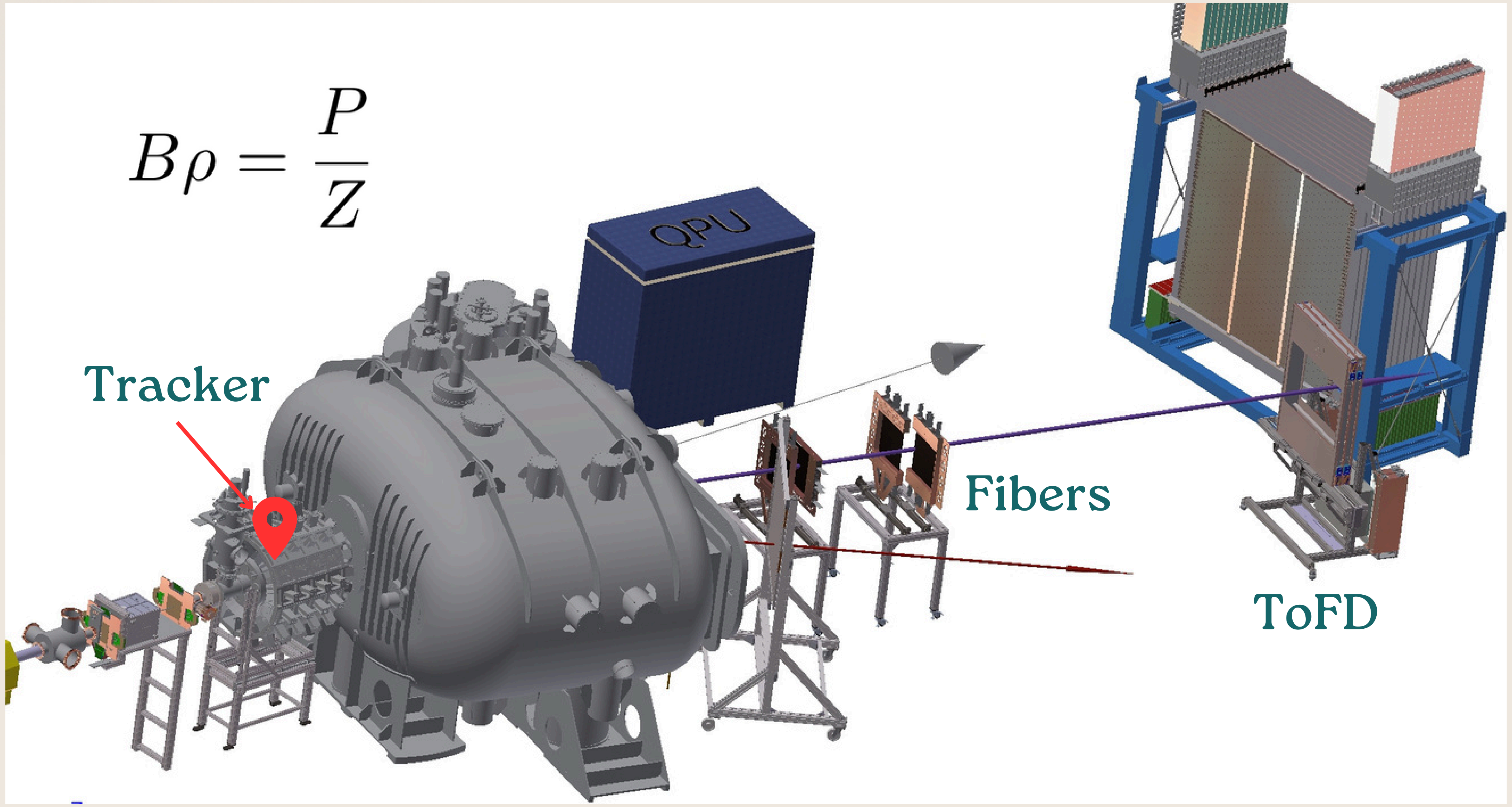
$$\langle E(1^+, 2^+)\rangle(^{18}C) = 7.77 \text{ MeV}$$

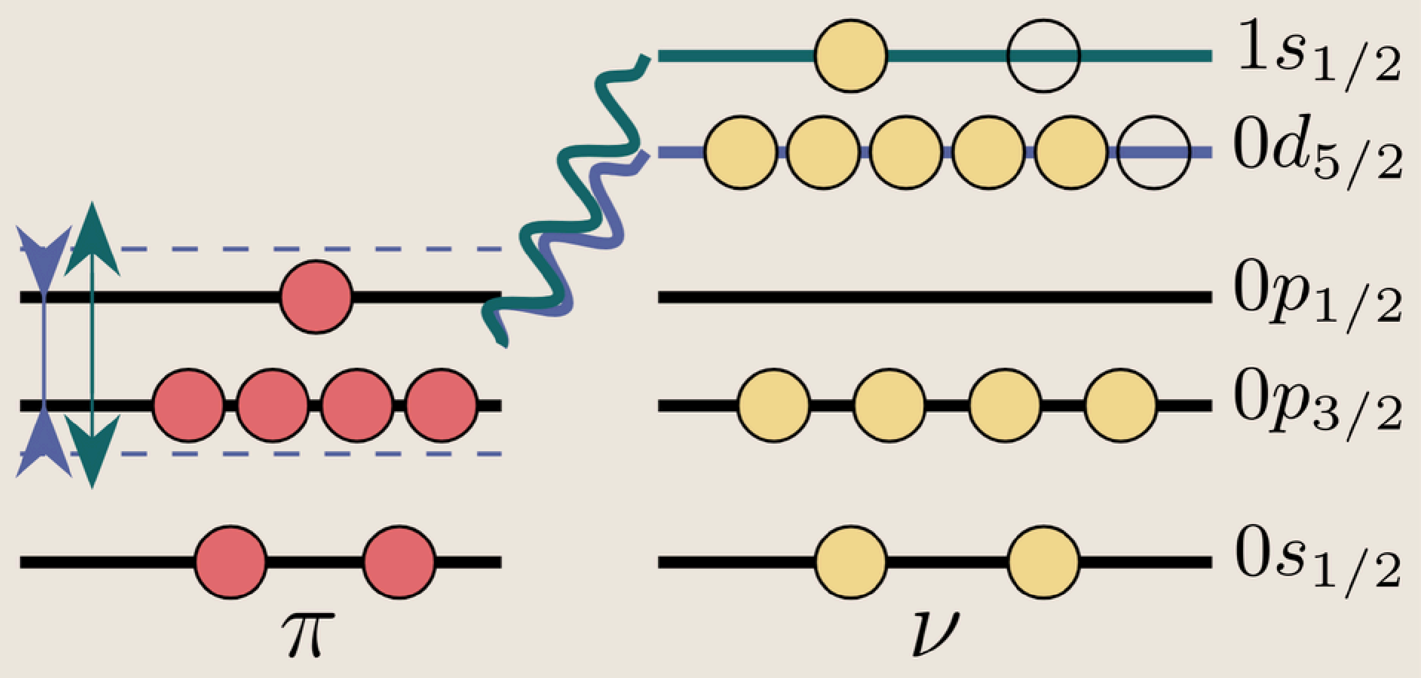
$$\langle E(1^+, 2^+)\rangle(^{14}C) = 9.15 \text{ MeV}$$

$$\Delta\langle E(1^+, 2^+)\rangle = -1.38 \text{ MeV}$$

Momentum reconstruction

orbital dependant → Study the filling of the neutron $1d_{5/2}$ and $2s_{1/2}$ orbitals

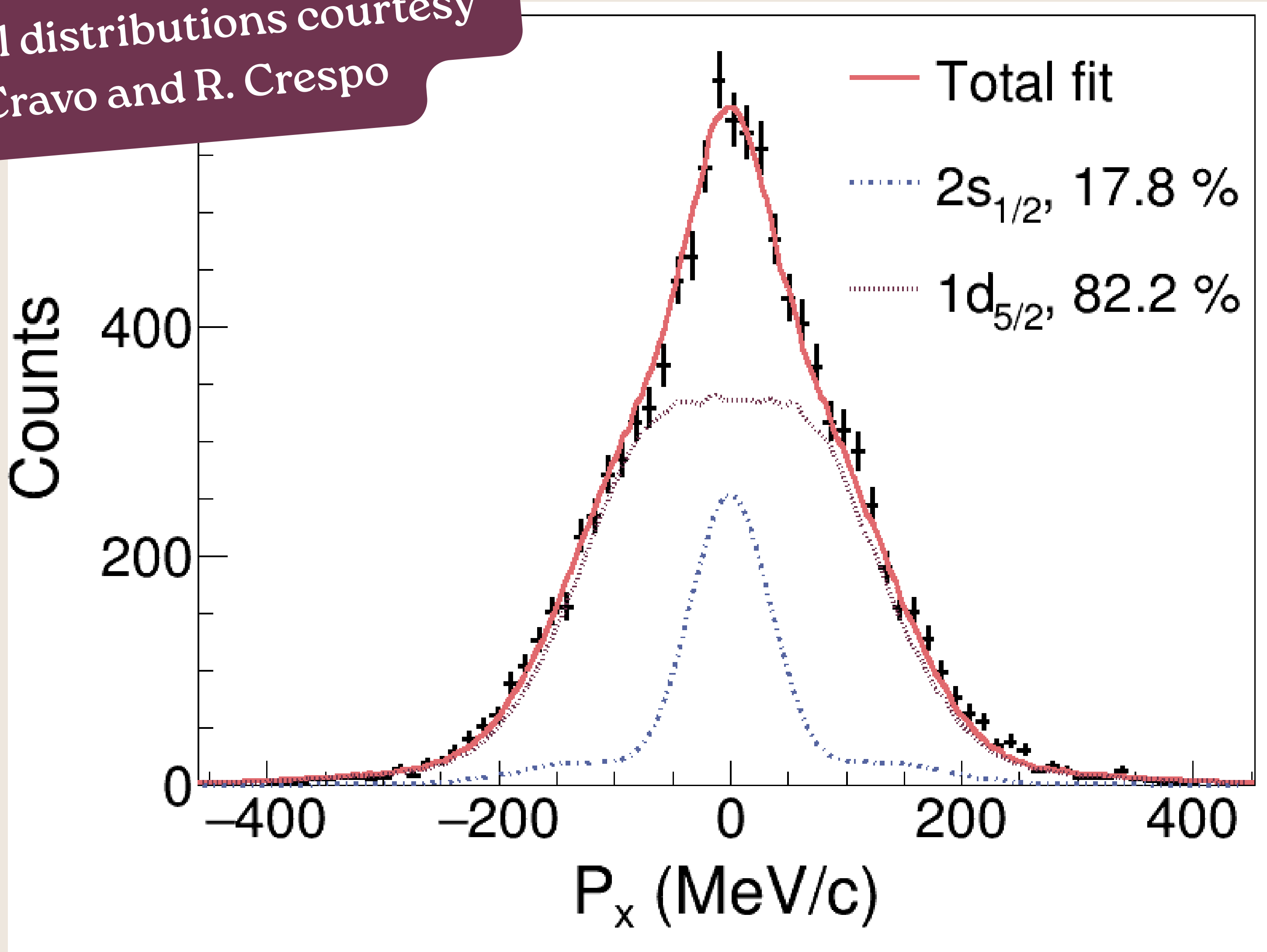


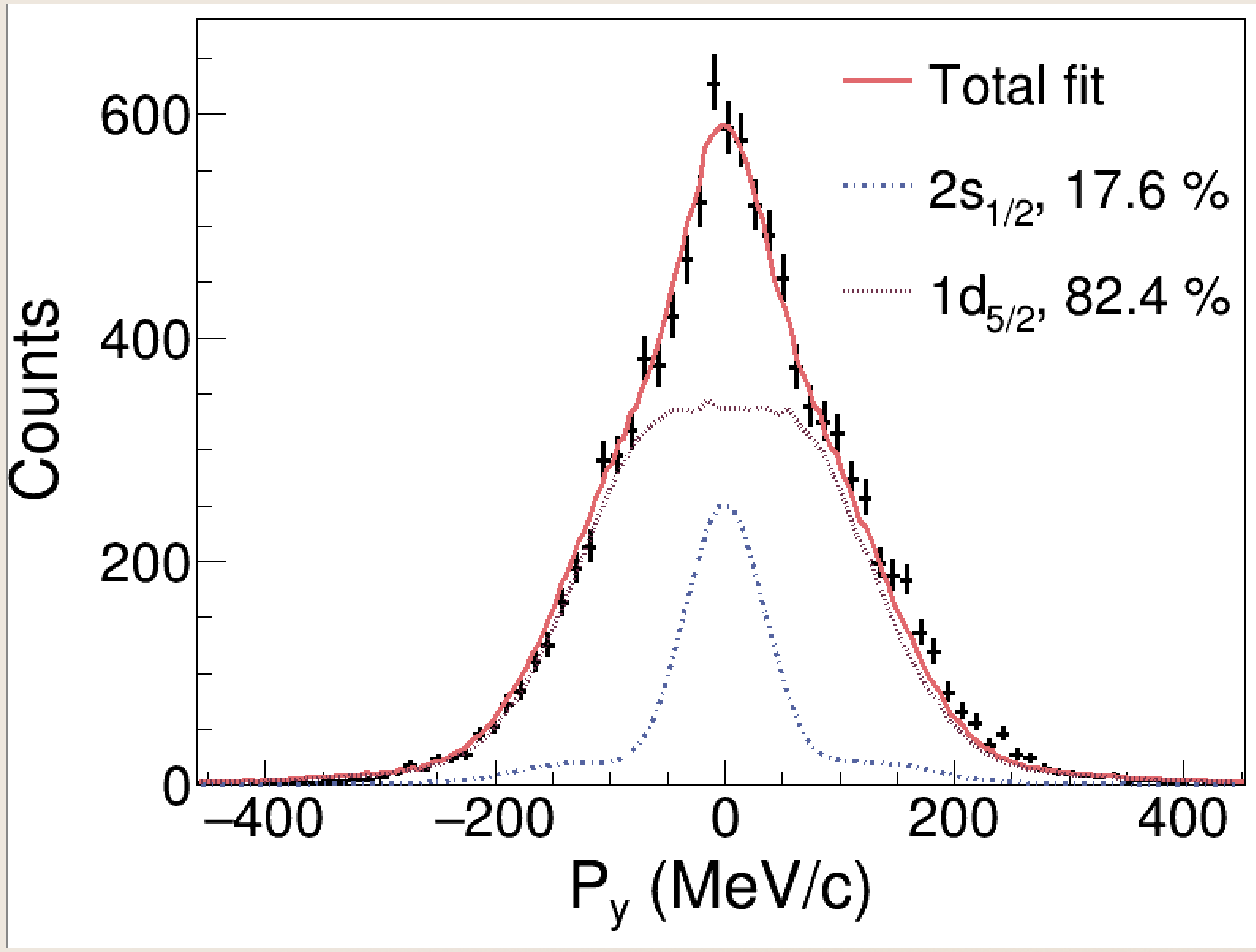


Momentum reconstruction

$^{18}C(p,pn)^{17}C$

Theoretical distributions courtesy of E. Cravo and R. Crespo





neutron occupancies

s-wave 0.707(44)

d-wave 3.292(88)

compatible with estimations from C^2S

Y. Kondo et al PRC 97 (2009) 014602

s-wave 0.604(90)

d-wave 3.66(55)

$^{19}N(p,2p)^{18}C$ bound + unbound

Estimation from TBME

$$\Delta V^{pn} = n_{d_{5/2}}\left(V^{pn}(p_{1/2}, d_{5/2}) - V^{pn}(p_{3/2}, d_{5/2})\right) + $$
$$+ n_{s_{1/2}}\left(V^{pn}(p_{1/2}, s_{1/2}) - V^{pn}(p_{3/2}, s_{1/2})\right)$$

from momentum distributions

$$V^m_{pn}(0p_{1/2}, 0d_{5/2}) = -2.072$$
$$V^m_{pn}(0p_{1/2}, 1s_{1/2}) = -1.079$$
$$V^m_{pn}(0p_{3/2}, 0d_{5/2}) = -1.647$$
$$V^m_{pn}(0p_{3/2}, 1s_{1/2}) = -1.384$$

C. Yuan et al., PRC 85 (2012) 064324

Energy centroid of the 1+ and 2+ states

$$\langle E(1^+, 2^+)\rangle(^{18}C) = 7.77 \text{ MeV}$$
$$\langle E(1^+, 2^+)\rangle(^{14}C) = 9.15 \text{ MeV}$$

$$\Delta\langle E(1^+, 2^+)\rangle = -1.38 \text{ MeV}$$

$$\Delta V^{pn} = \Delta\langle E(1^+, 2^+)\rangle = -1.347 \text{ MeV}$$ Y. Kondo

$$\Delta V^{pn} = \Delta\langle E(1^+, 2^+)\rangle = -1.193 \text{ MeV}$$ This work

Summary

QFS reactions on the neutron-rich N region are being sucessfully studied

- Momentum distributions are good observables to determine neutron $0d_{5/2}$ and $1s_{1/2}$ fillings
- Systematic inclusive σ along the N chain
  - confirms the 1n halo structure in ^{19}C
  - quenching is compatible with previously observed trend at high proton-neutron asymmetry
- Exclusive $^{19}N(p,2p)^{18}C$ study observe unbound states compatible with previous works and hints a quenching of the Z=6 gap towards the neutron dripline

Outlook

- 2n decay
- ^{20}C?

Special thanks to:

A. Barrière, N. Mozumdar, J. L. Rodríguez-Sánchez, O. Sorlin

R^3B Collaboration