高能与低能核物理交叉学术研讨会



Exotic Decays and Related Phenomena

Simin Wang (S. M. Wang)

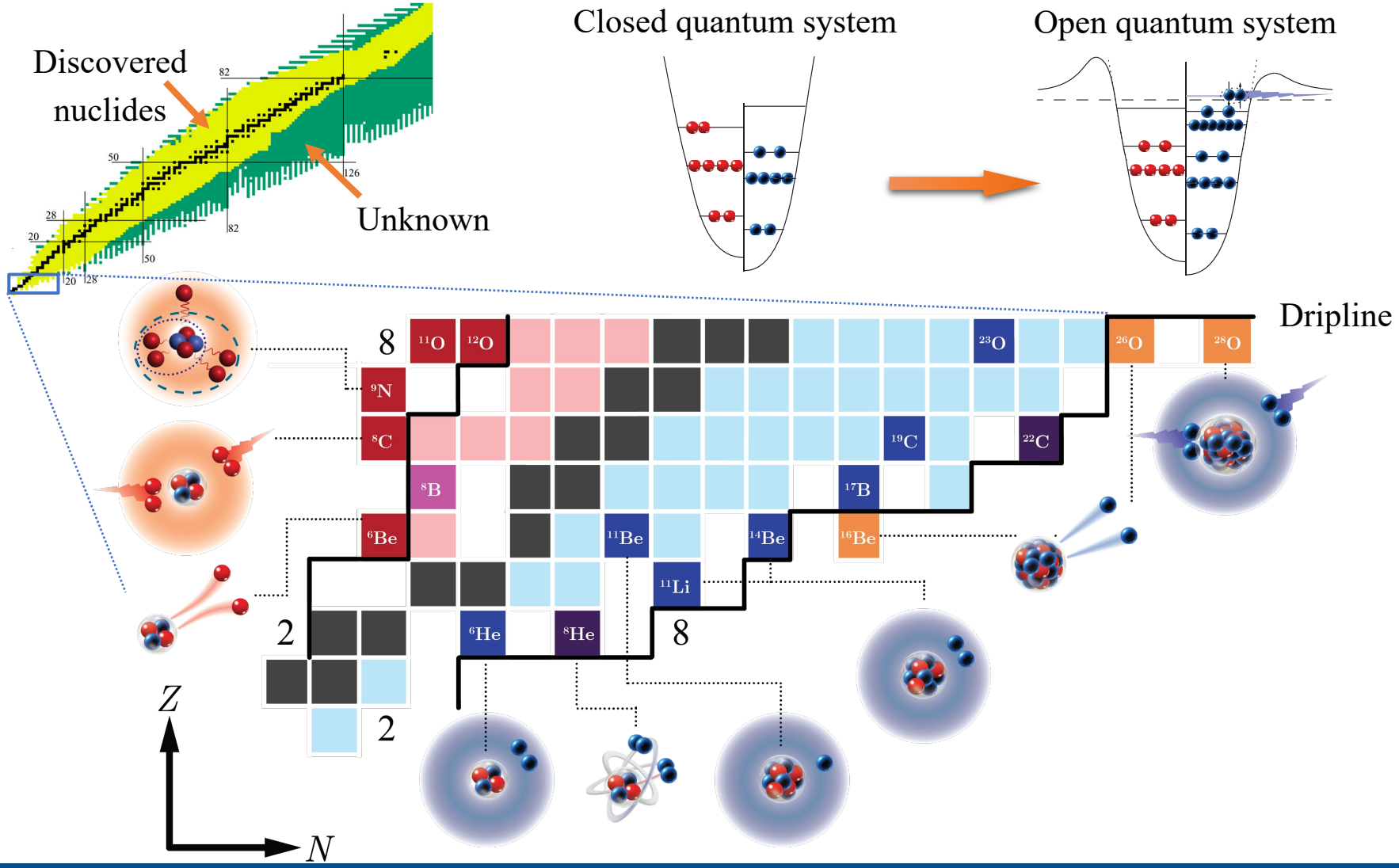
Fudan University

Collaborators: Y. G. Ma, W. Nazarewicz,

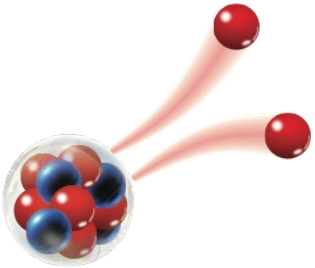
F. R. Xu, M. Pfützner, I. Mukha, R. J. Charity, A. Volya …



New physics towards the dripline

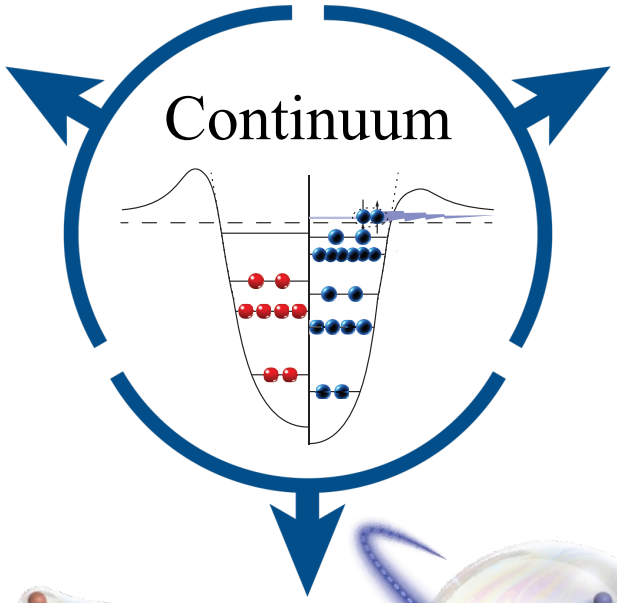


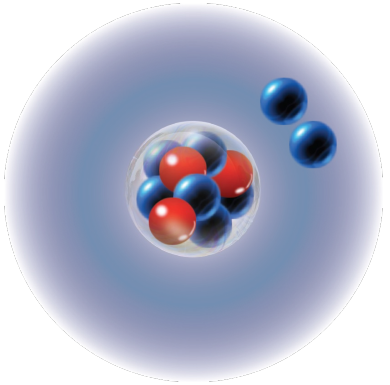
Continuum-impacted phenomena



Rare decay modes

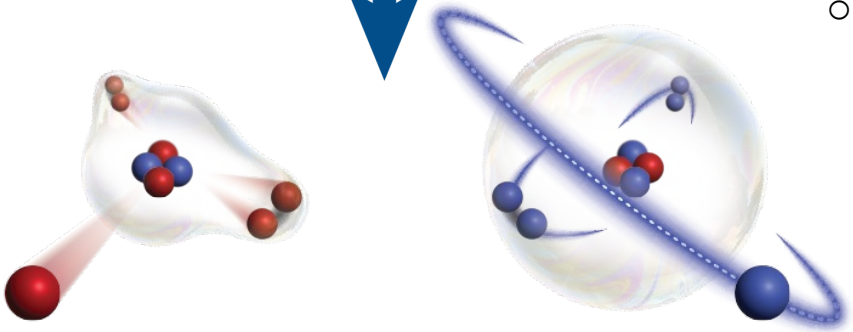
- $2p/2n$ decays
- Multi-particle emissions
- …





Exotic structures

- Halo & clustering
- New magic number
- …

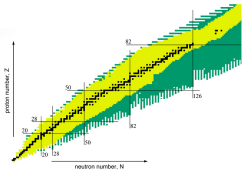


Mirror symmetry breaking

Outline

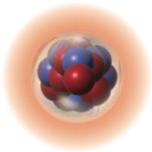
Introduction 1

- Dripline region
- Continuum effect



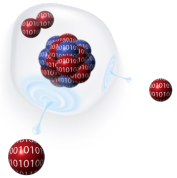
Radius 2

- Complex radius
- Halo-like enhancement



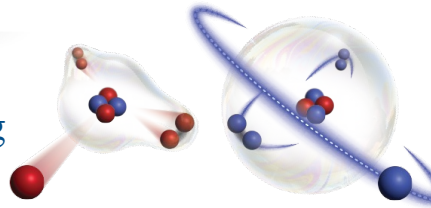
Decay 3

- 2*p* decay
- *pp* correlation

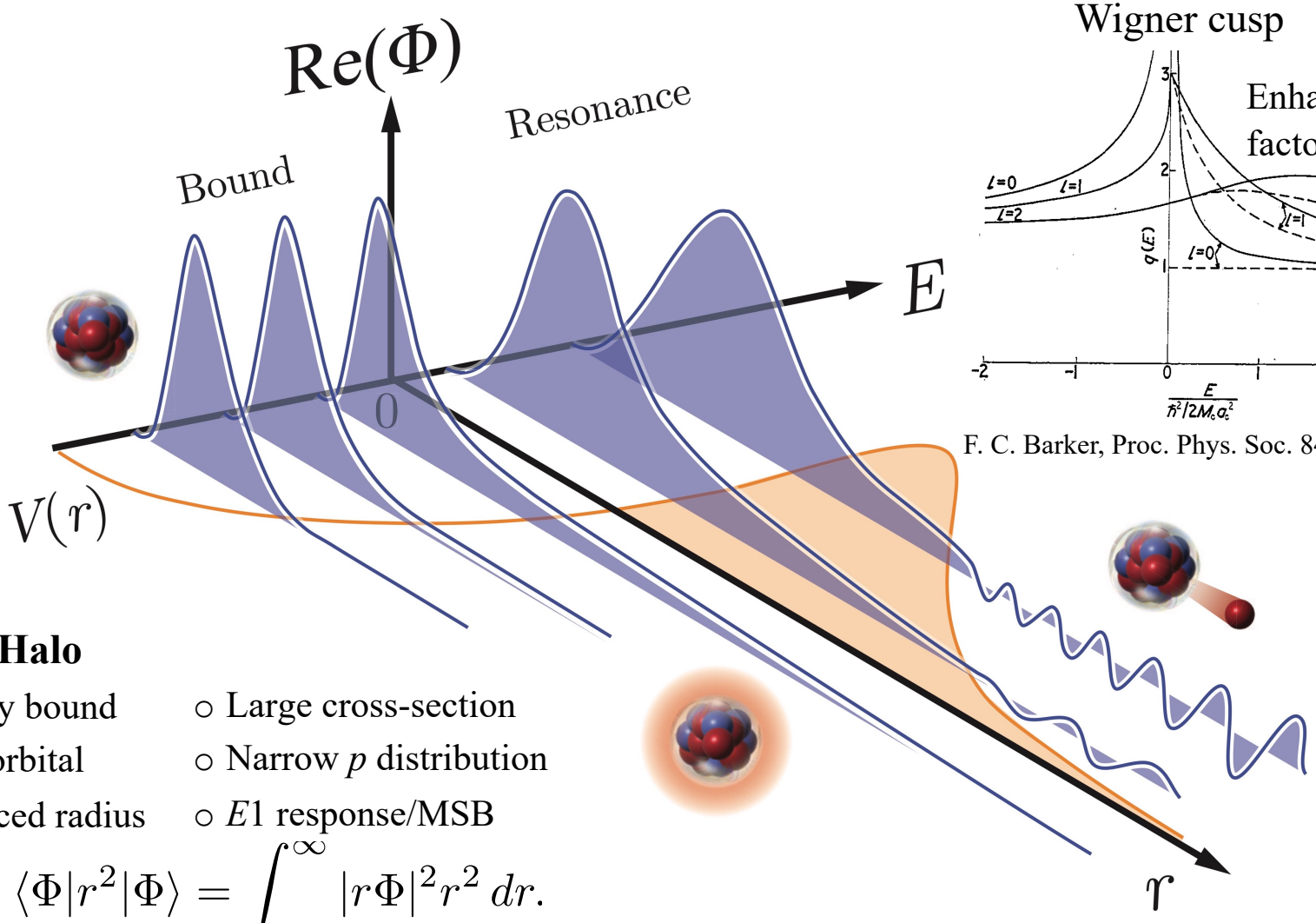


Mirror 4

- Thomas-Ehrman effect
- Mirror symmetry breaking



Contiuum effect



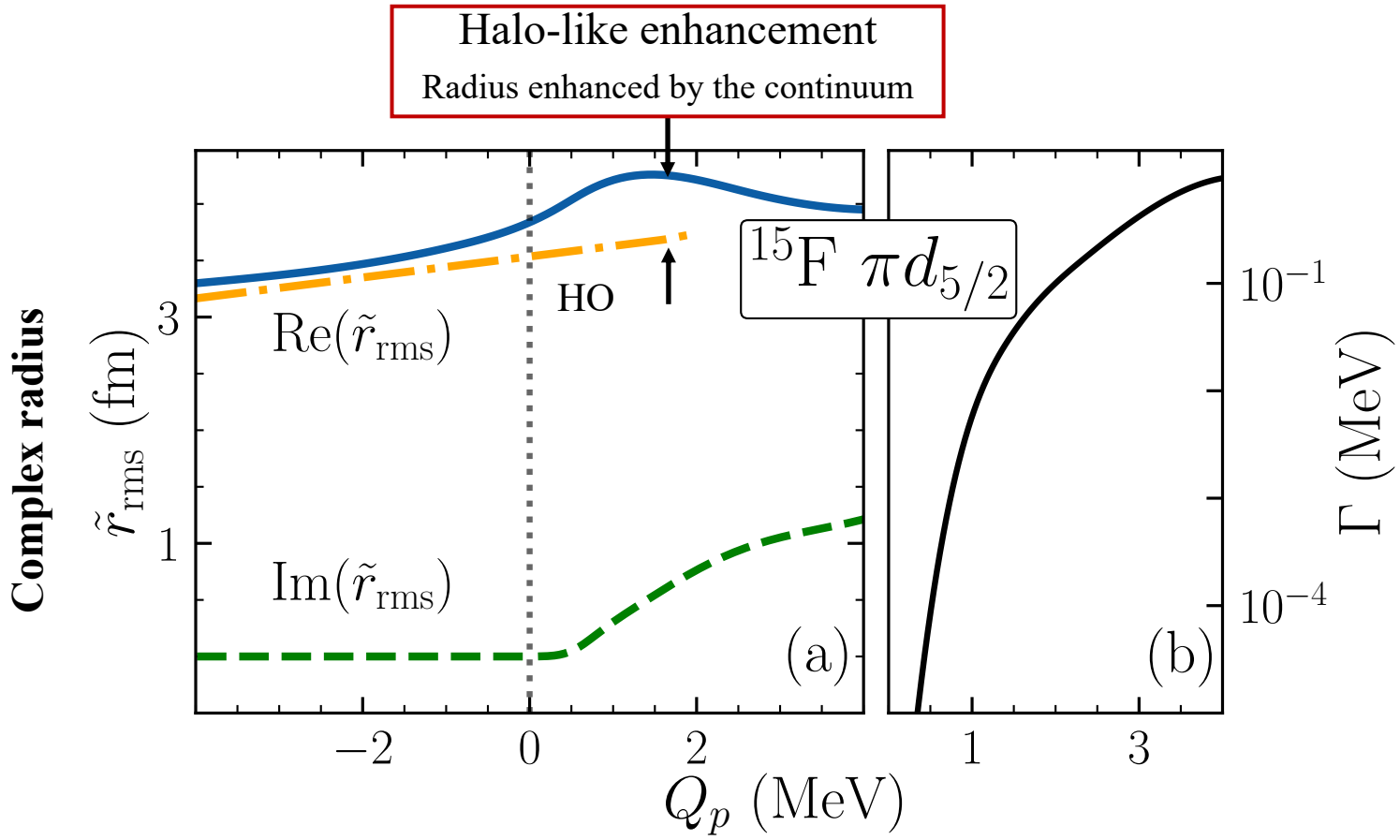
F. C. Barker, Proc. Phys. Soc. 84, 681 (1964)

Halo

- Weakly bound
- low-*l* orbital
- Enhanced radius
- Large cross-section
- Narrow *p* distribution
- *E*1 response/MSB

$$r_{\mathrm{rms}}^2 \equiv \langle \Phi | r^2 | \Phi \rangle = \int_0^\infty |r\Phi|^2 r^2 \, dr.$$

Complex radius of unbound system

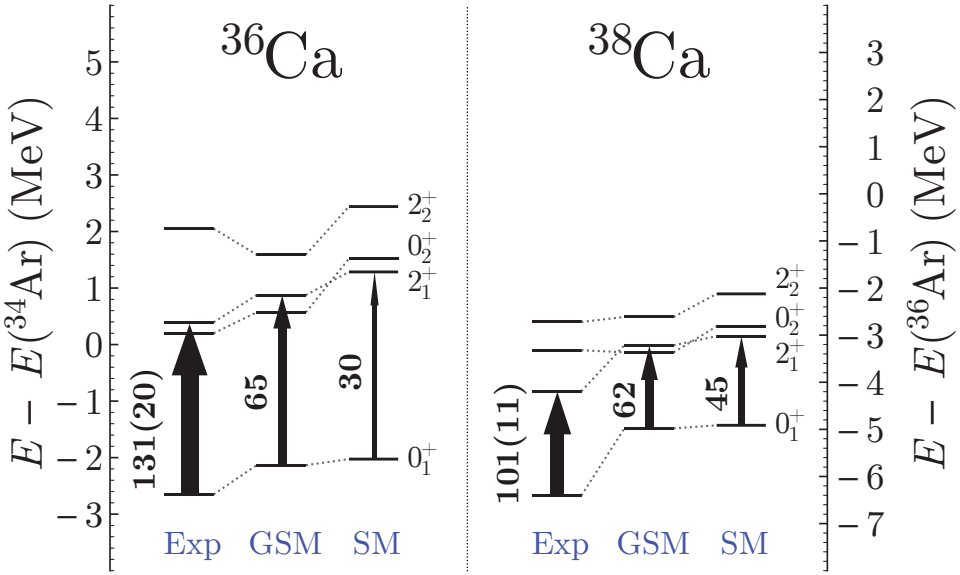


- Contiuum coupling is enhanced near the threshold.
- Complex radius $\tilde{r}^2_{\rm rms} \equiv \langle\tilde{\Phi}|r^2|\Phi\rangle = \int_0^\infty (r\Phi)^2 r^2\, dr.$

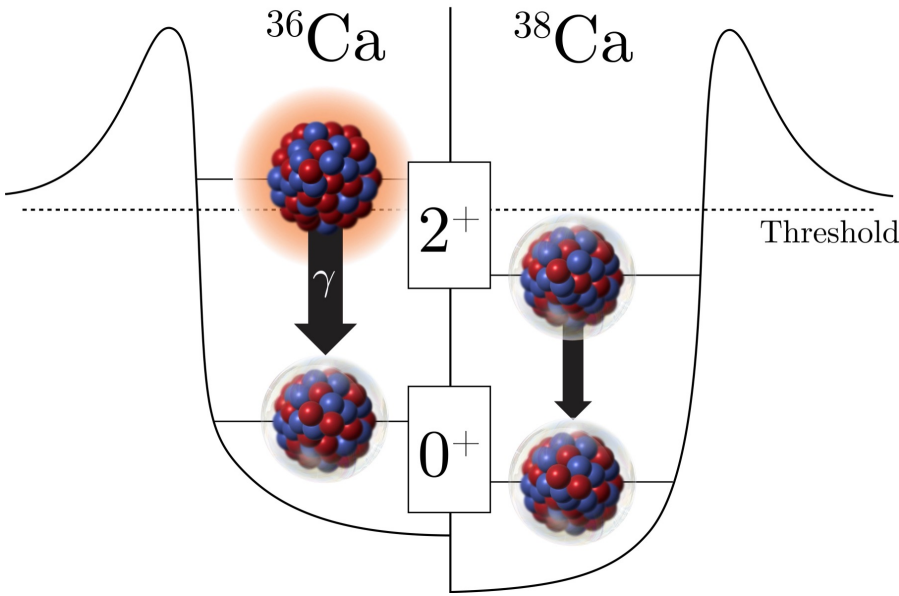
Y. R. Lin, SW, and W. Nazarewicz, PRL 136, 122501 (2026)
T. Myo and K. Katō, PTEP 2014, 083D01 (2014).

Contiuum effect on electromagnetic transition

Spectra and $B(E2)$ values of ^{36,38}Ca



Density evolution



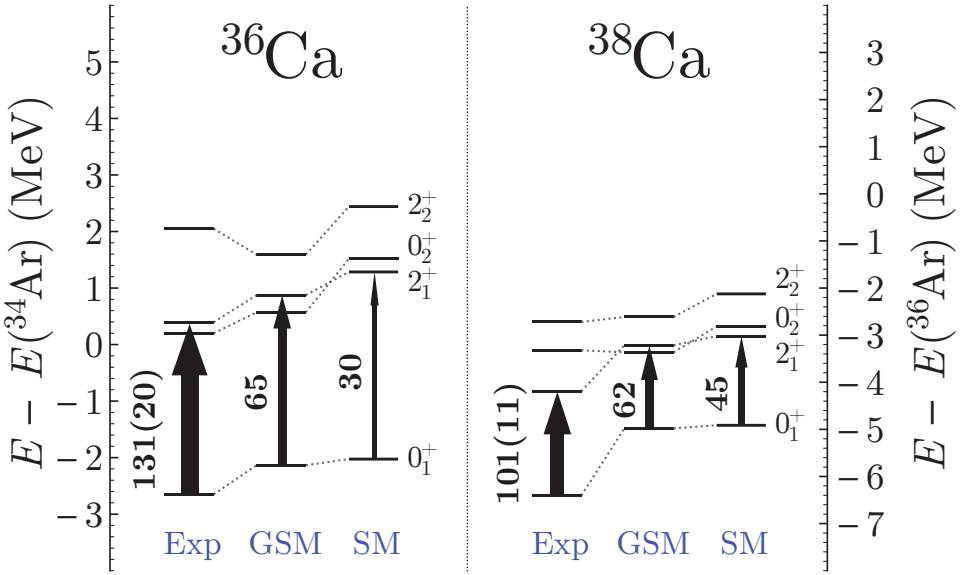
$$\rho_L(r) = \langle \Phi_f | \frac{1}{r^2} \delta(r' - r) Y_L | \Phi_i \rangle$$

$$B(EL) = \left[\frac{\hat{J}_f}{\hat{J}_i} \int_0^\infty \rho_L(r) r^{L+2} dr \right]^2$$

Z. Xu, SW *et al.*, PRC 112, L011302 (2025).
T. Beck, A. Gade *et al.*, PRC 108, L061301 (2023)
N. Dronchi, D. Weisshaar *et al.*, PRC 107, 034306 (2023)

Contiuum effect on electromagnetic transition

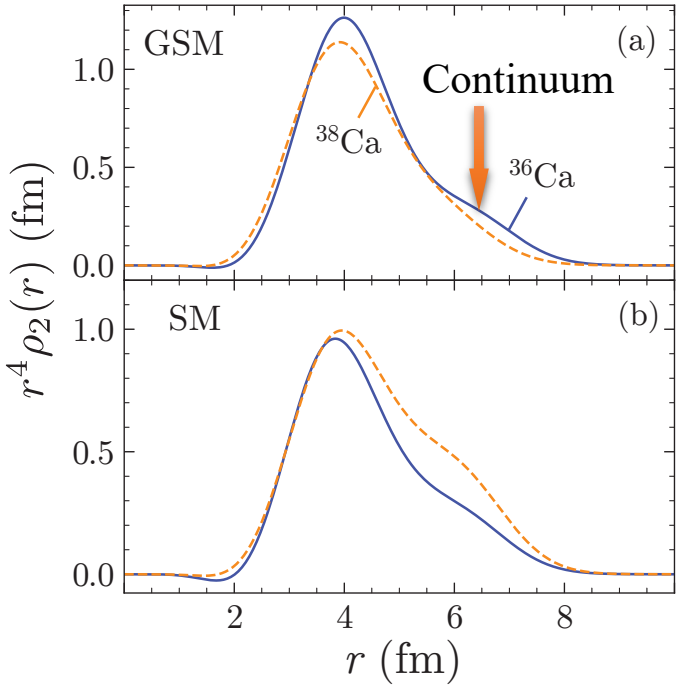
Spectra and $B(E2)$ values of ^{36,38}Ca



$$\rho_L(r) = \langle \Phi_f | \frac{1}{r^2} \delta(r' - r) Y_L | \Phi_i \rangle$$

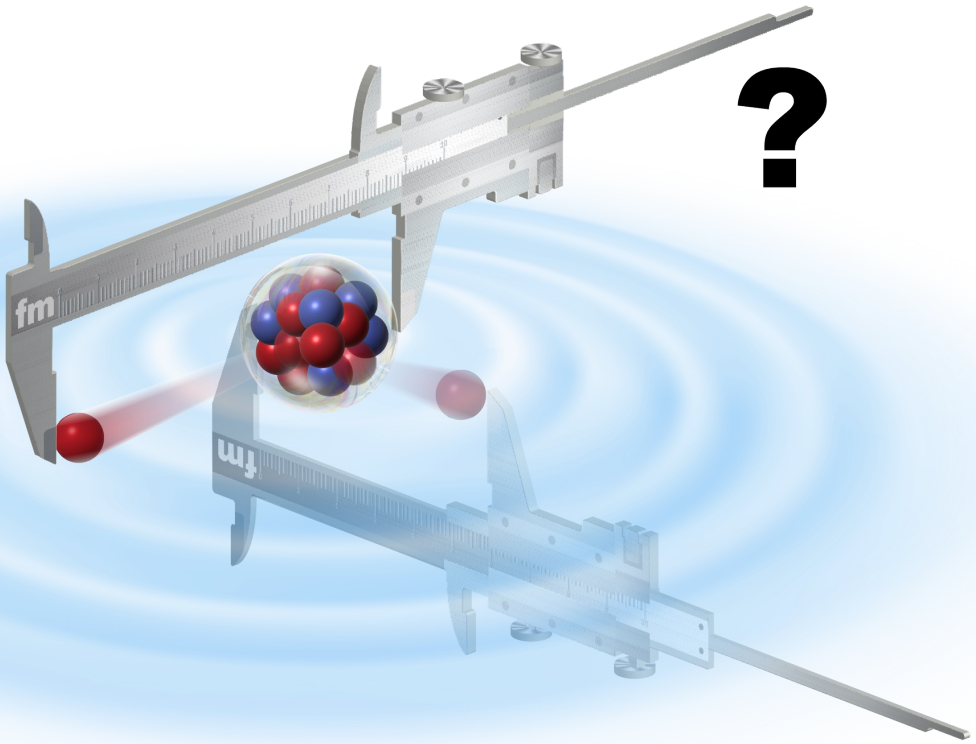
$$B(EL) = \left[\frac{\hat{J}_f}{\hat{J}_i} \int_0^\infty \rho_L(r) r^{L+2} dr \right]^2$$

$E2$ ($0^+ \rightarrow 2^+$) Transition densities



Z. Xu, SW *et al.*, PRC 112, L011302 (2025).
T. Beck, A. Gade *et al.*, PRC 108, L061301 (2023)
N. Dronchi, D. Weisshaar *et al.*, PRC 107, 034306 (2023)

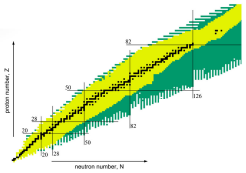
How to extract structures of unbound nuclei



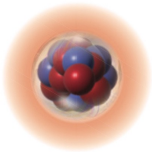
Decay properties might help

Outline

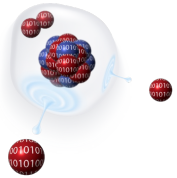
Introduction 1
- Dripline region
- Continuum effect



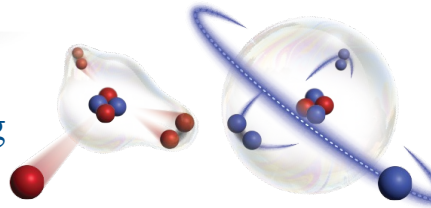
Radius 2
- Complex radius
- Halo-like enhancement



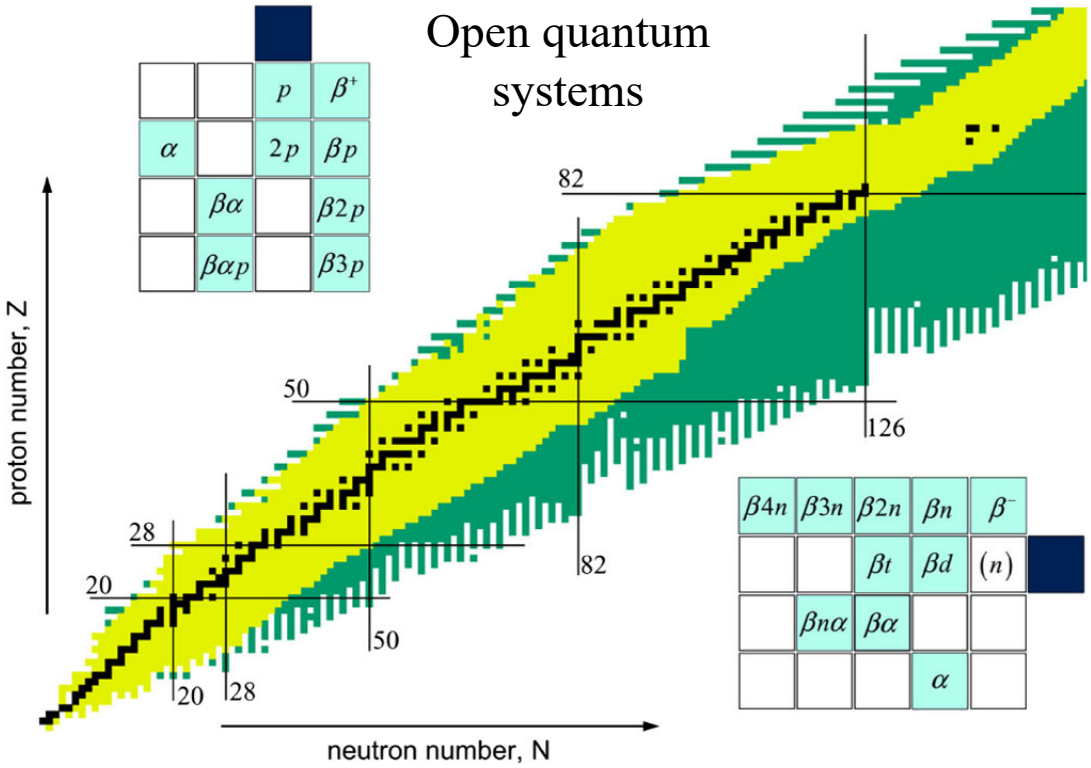
Decay 3
- 2*p* decay
- *pp* correlation



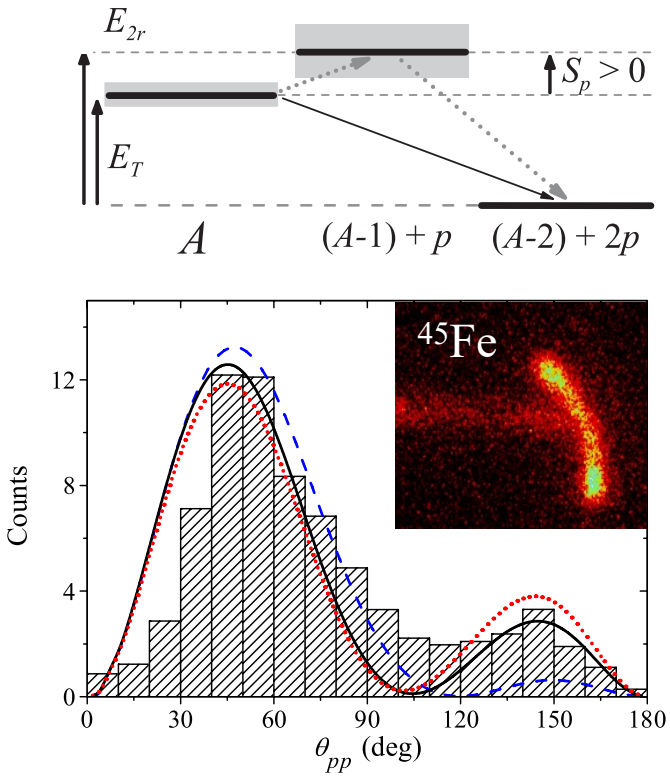
Mirror 4
- Thomas-Ehrman effect
- Mirror symmetry breaking



Exotic two-proton (2*p*) decay



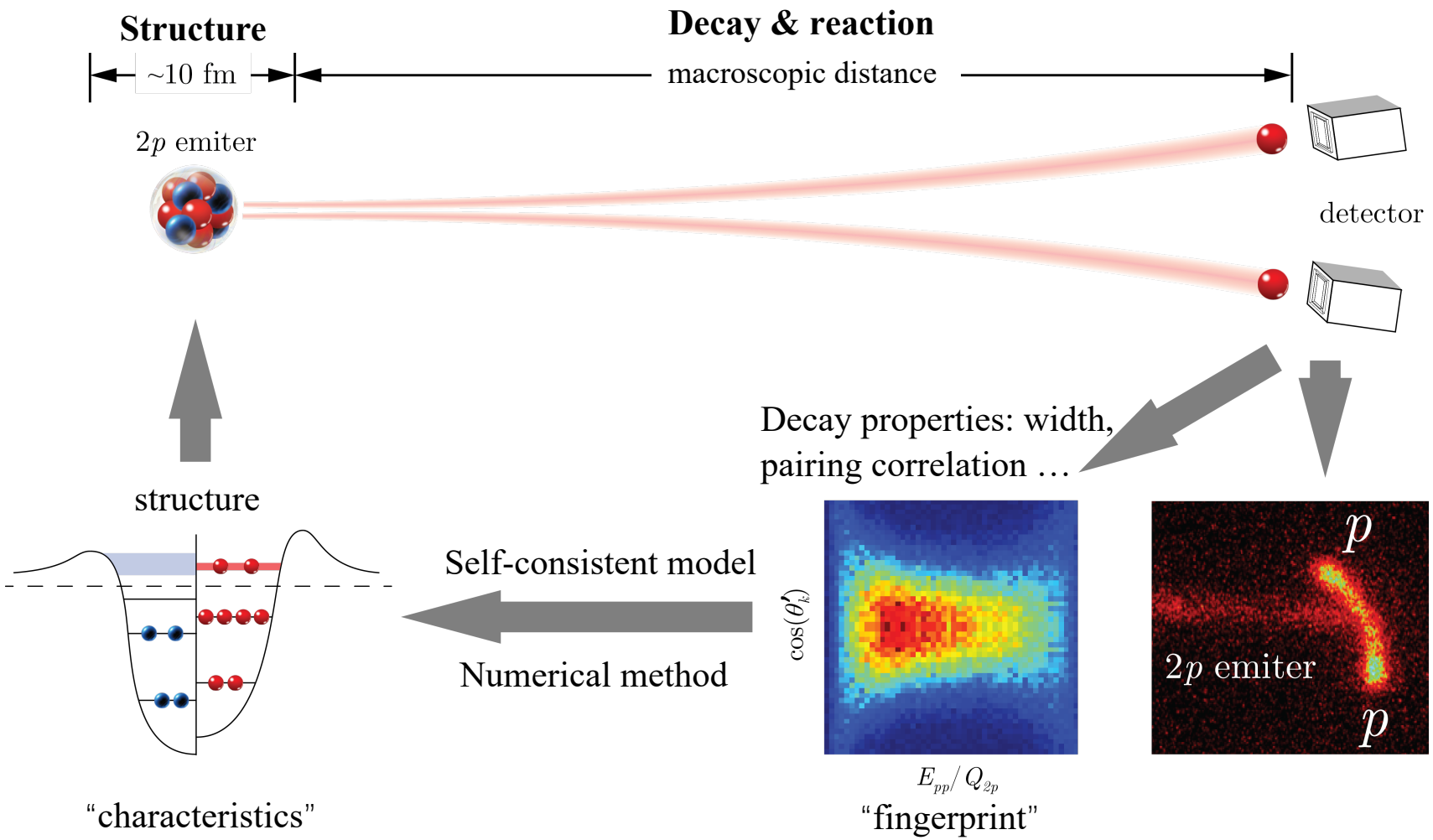
- **2*p* decay**



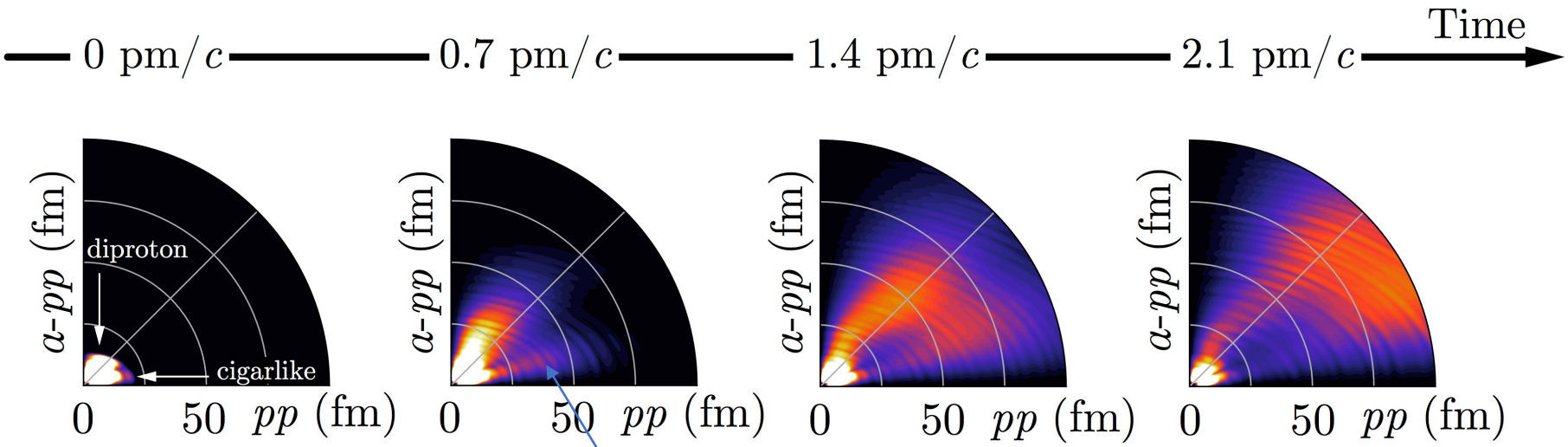
Y.B. Zeldovich, Sov. Phys. JETP 11, 812 (1960)
V. Goldansky, NP 19, 482 (1960)

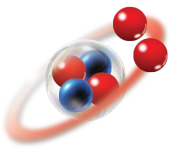
J. Giovinazzo *et al.*, PRL 89, 102501 (2002)
K. Miernik *et al.*, PRL 99, 192501 (2007)

Structure ⟷ Asymptotic observables

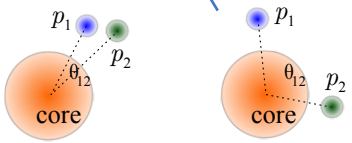


2*p* decay in ^{6}Be

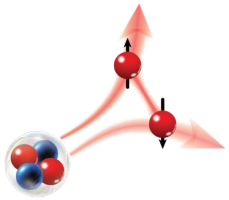




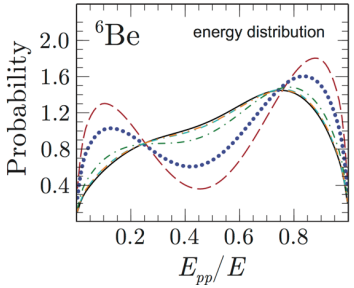
Protons inside nucleus



Two types of tunneling:
1. diproton (primarily)
2. cigarlike



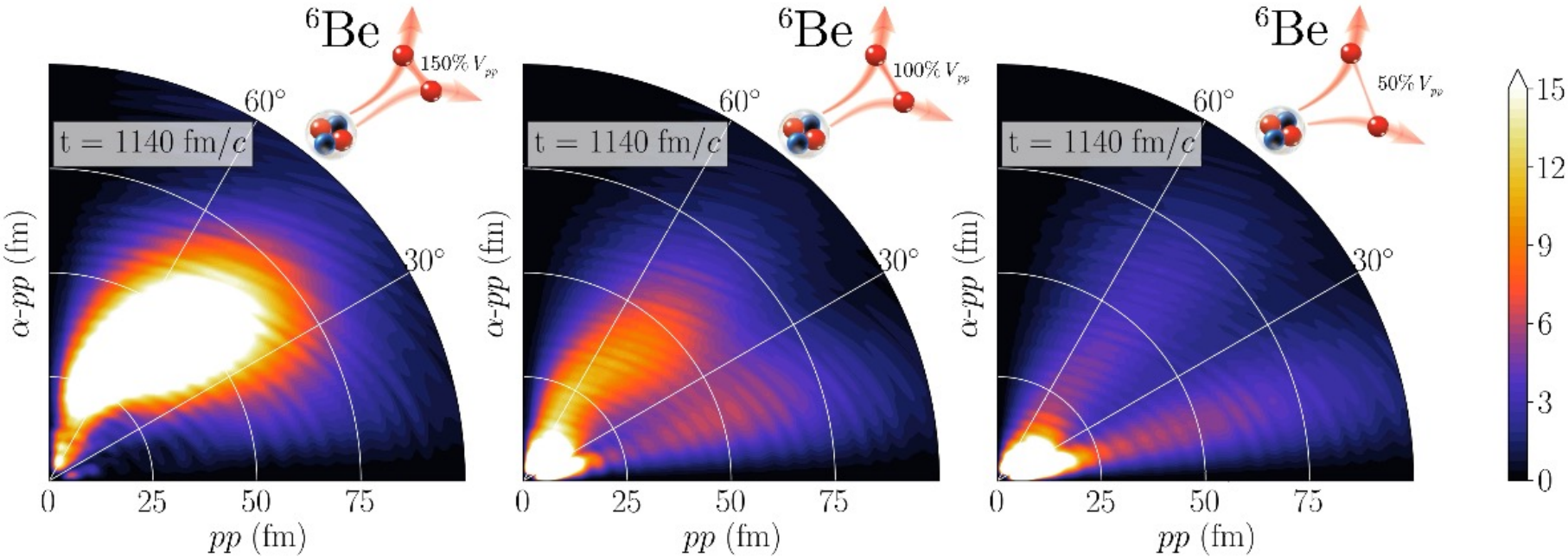
Diproton branch bends due to Coulomb repulsion



Asymptotic correlation begin to converge

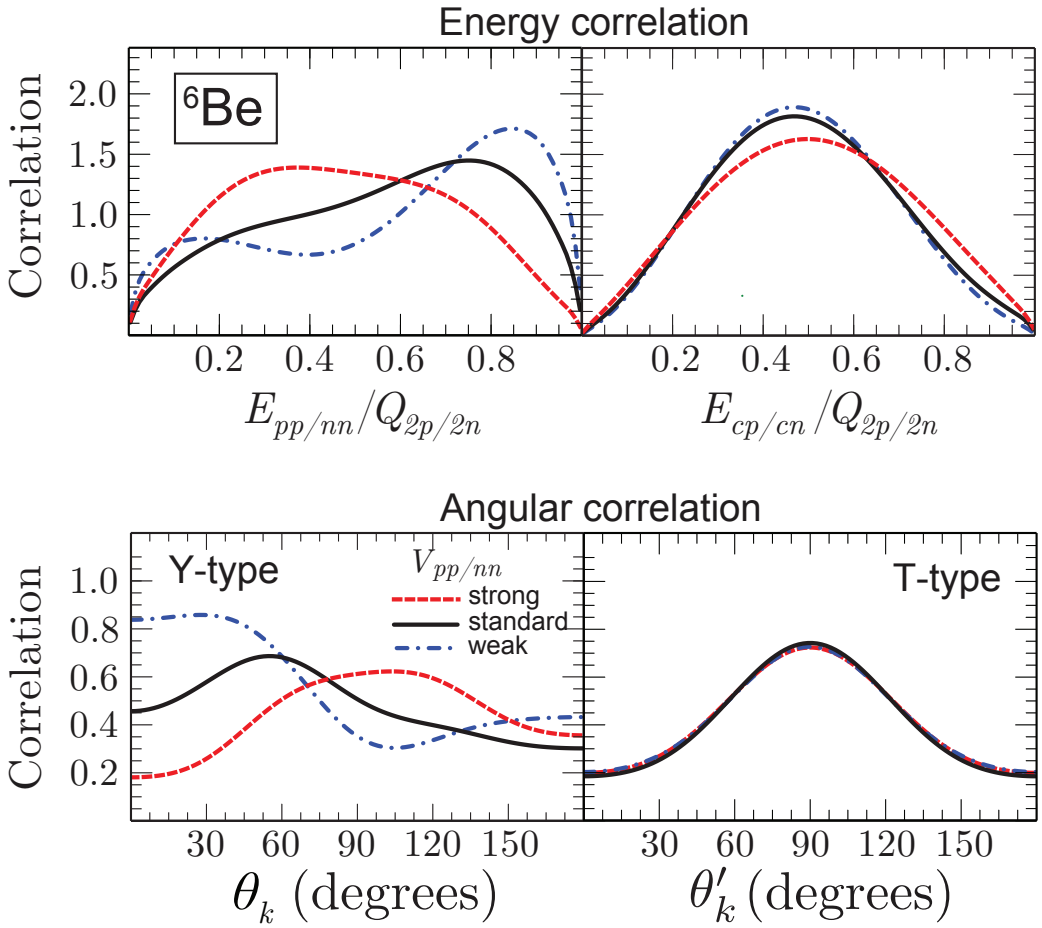
SW and W. Nazarewicz, PRL 126, 142501 (2021)

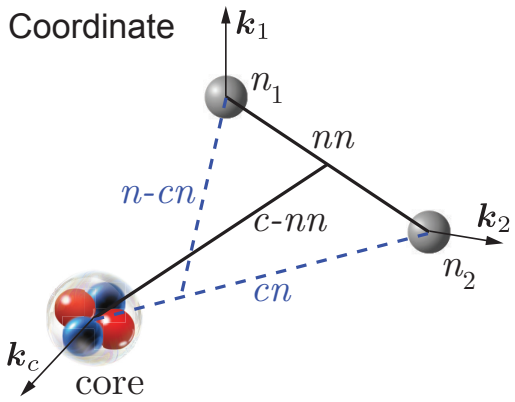
Decay dynamics depends on pairing

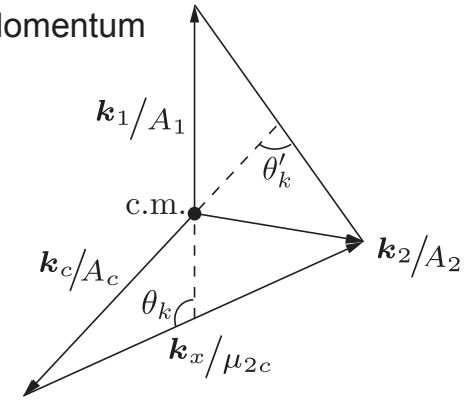


- The decay dynamics as well as correlation strongly depend on the pairing strength.
- Strong pairing results in a larger decay width, which indicates that pairing will benefit the 2*p* tunneling.

Asymptotic correlations







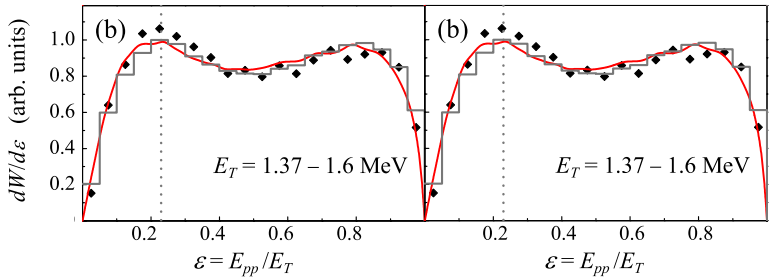
○ E_{pp} and Y-type angular correlations are strongly impacted by nucleon-nucleon interaction.

Exotic phenomena of 2*p* decay



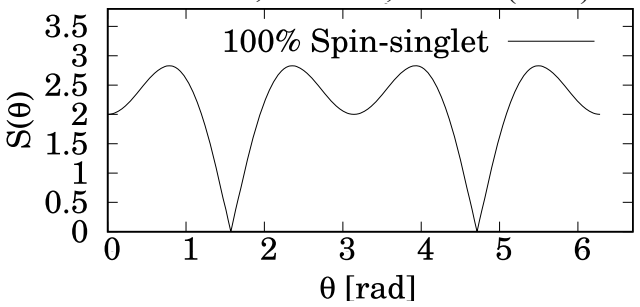
2*p* decay

I. A. Egorova *et al.*, PRL 109, 202502 (2012)



E-dependent nn correlation

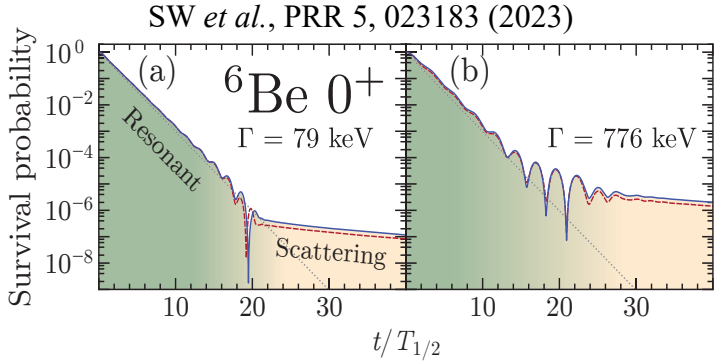
T. Oishi, PLB 862, 139361 (2025)



Entanglement

See Prof. T. Oishi's talks and Z. X. Shen's poster

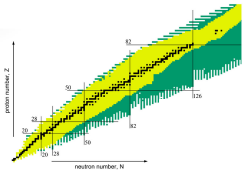
SW *et al.*, PRR 5, 023183 (2023)



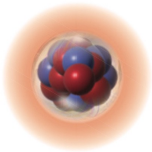
Non-exp decay

Outline

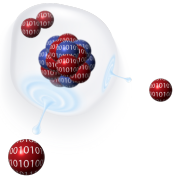
Introduction 1
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- Continuum effect



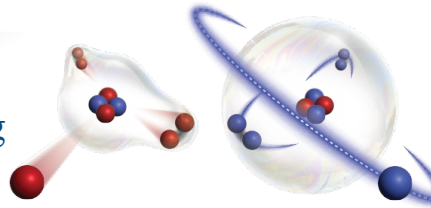
Radius 2
- Complex radius
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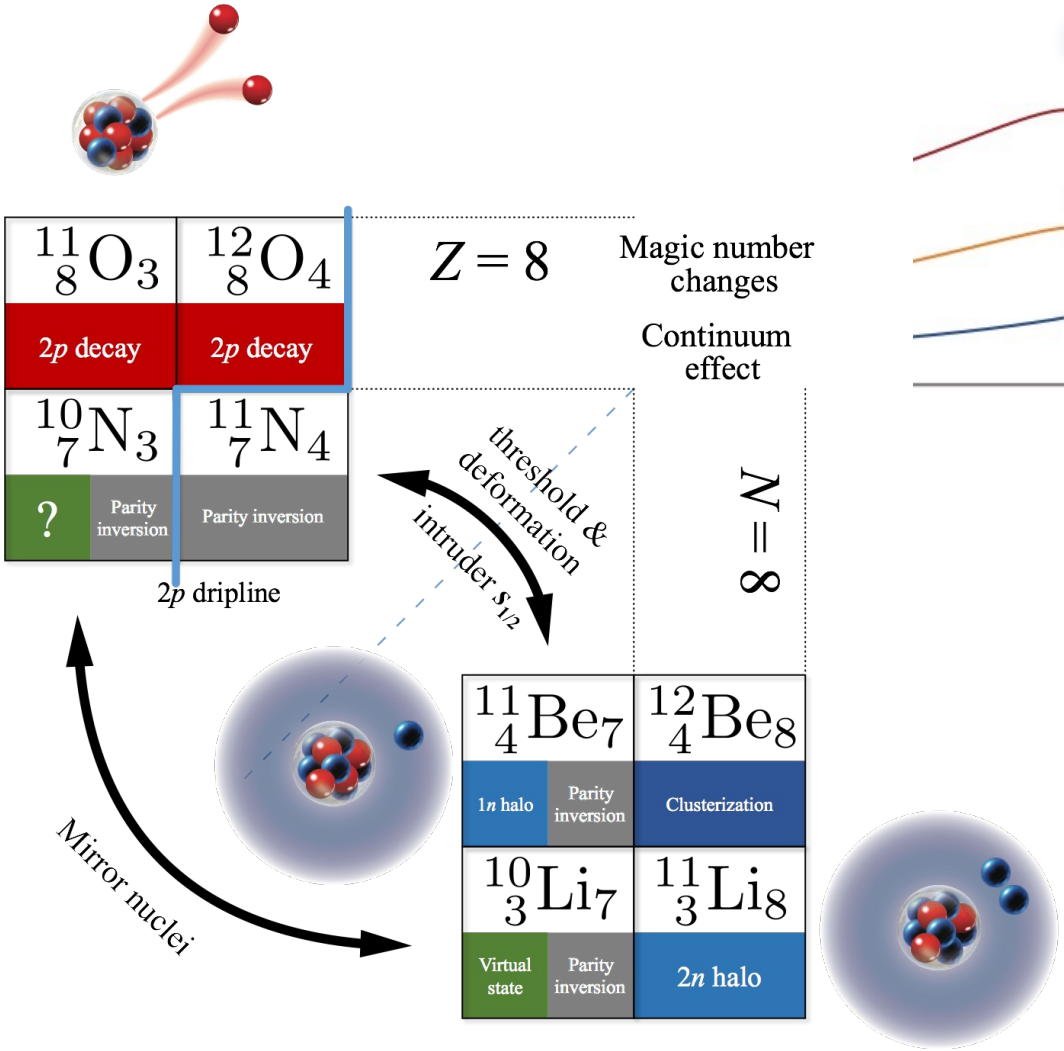
Decay 3
- 2*p* decay
- *pp* correlation

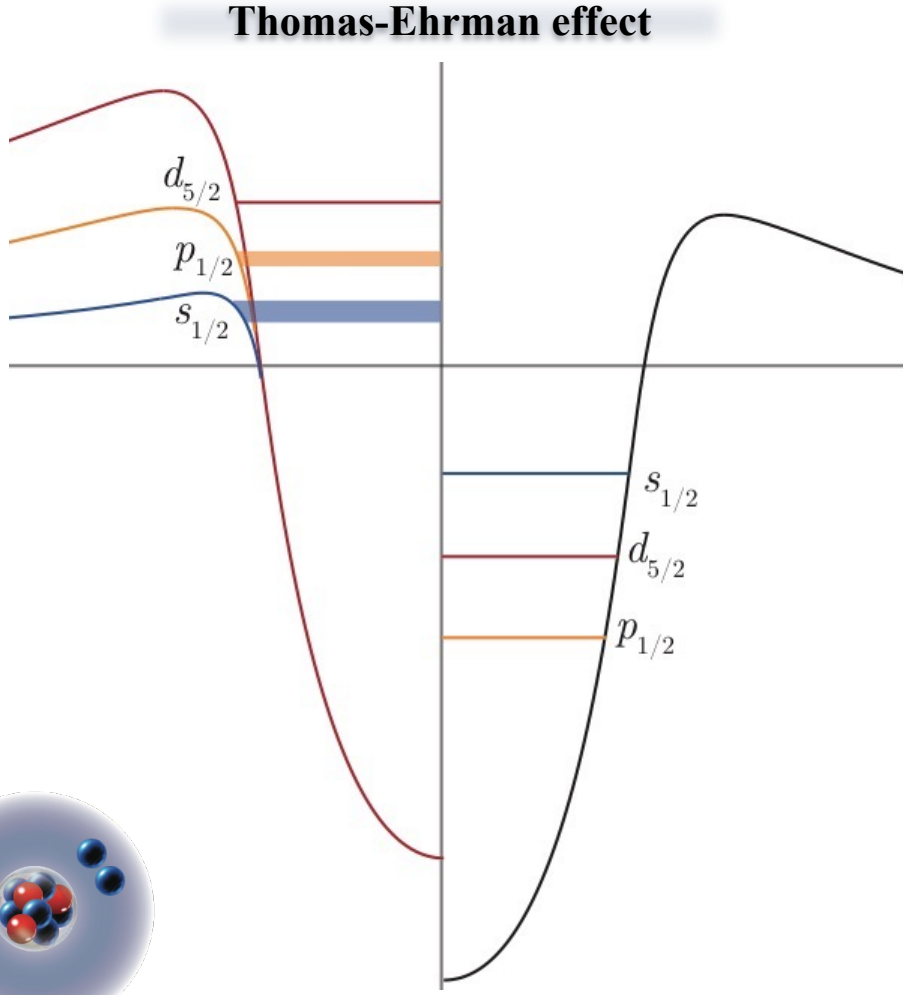


Mirror 4
- Thomas-Ehrman effect
- Mirror symmetry breaking



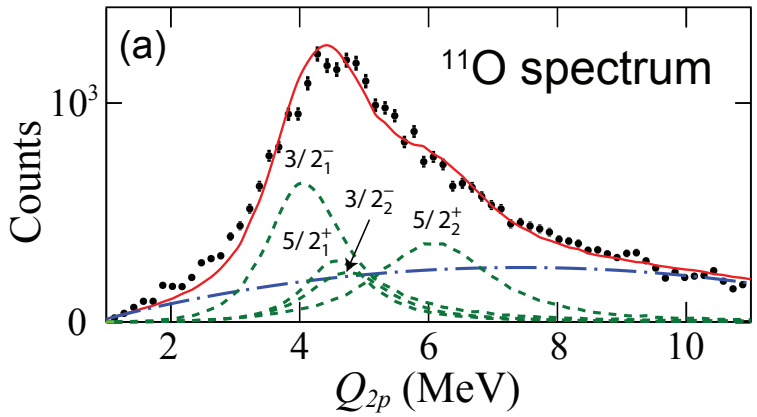
Mirror structure probed by 2*p* decay



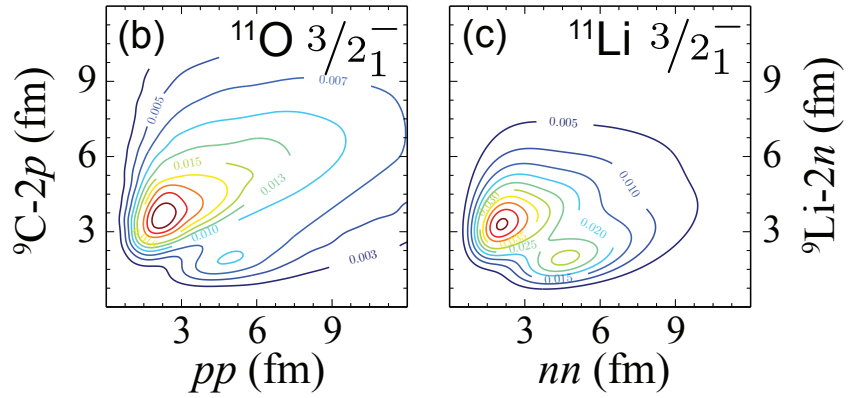


Predicted spectrum and structure of ^{11}O

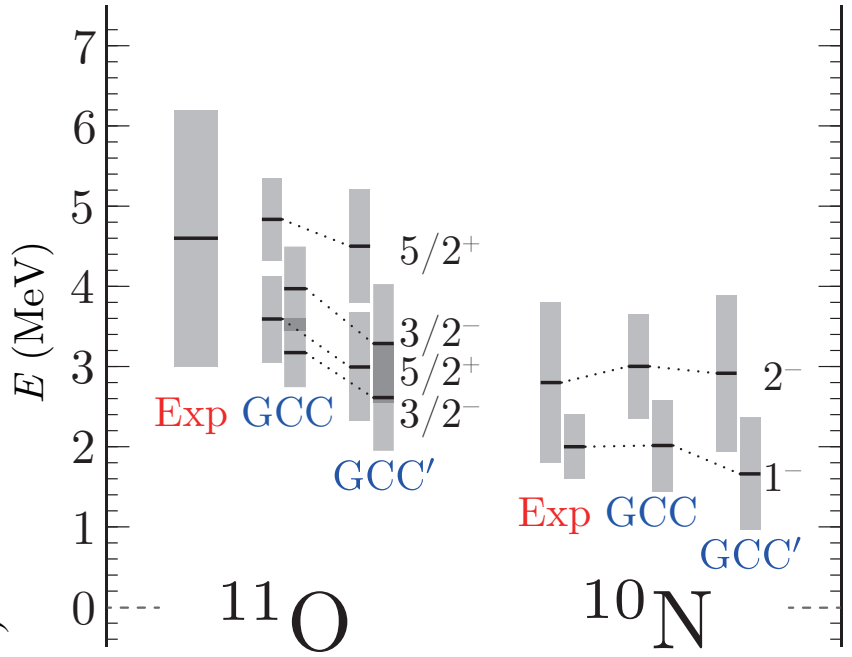
Measured spectrum of ^{11}O



Density distributions of ^{11}O and ^{11}Li



Calculated spectra of ^{10}N, ^{11}O

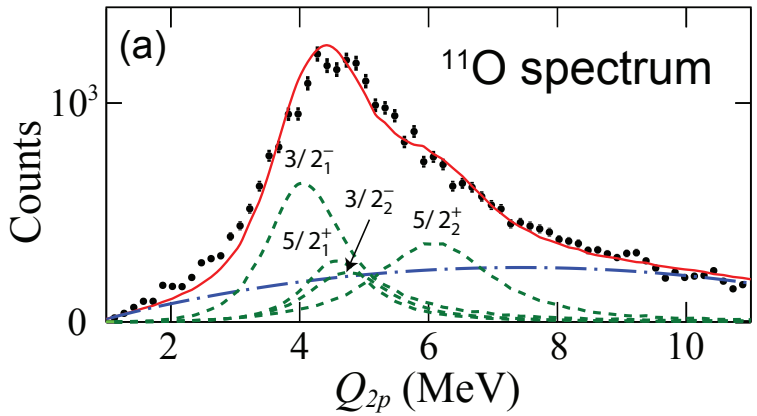


T. Webb *et al.*, PRL 122, 122501 (2019)

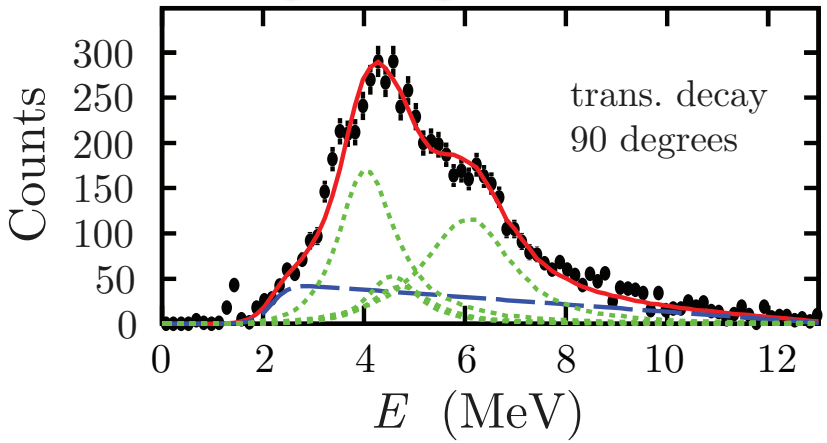
- The detected broad peak can be reproduced by four states rather than one.
- Mirror systems ^{11}O and ^{11}Li.

Predicted spectrum and structure of ^{11}O

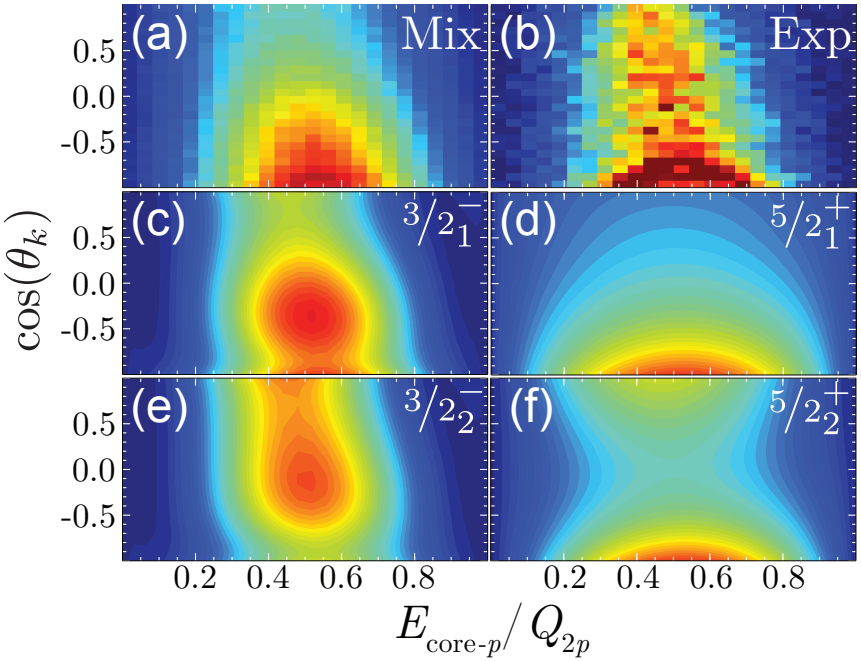
Measured spectrum of ^{11}O



Updated spectrum of ^{11}O



Asymptotic correlation of ^{11}O

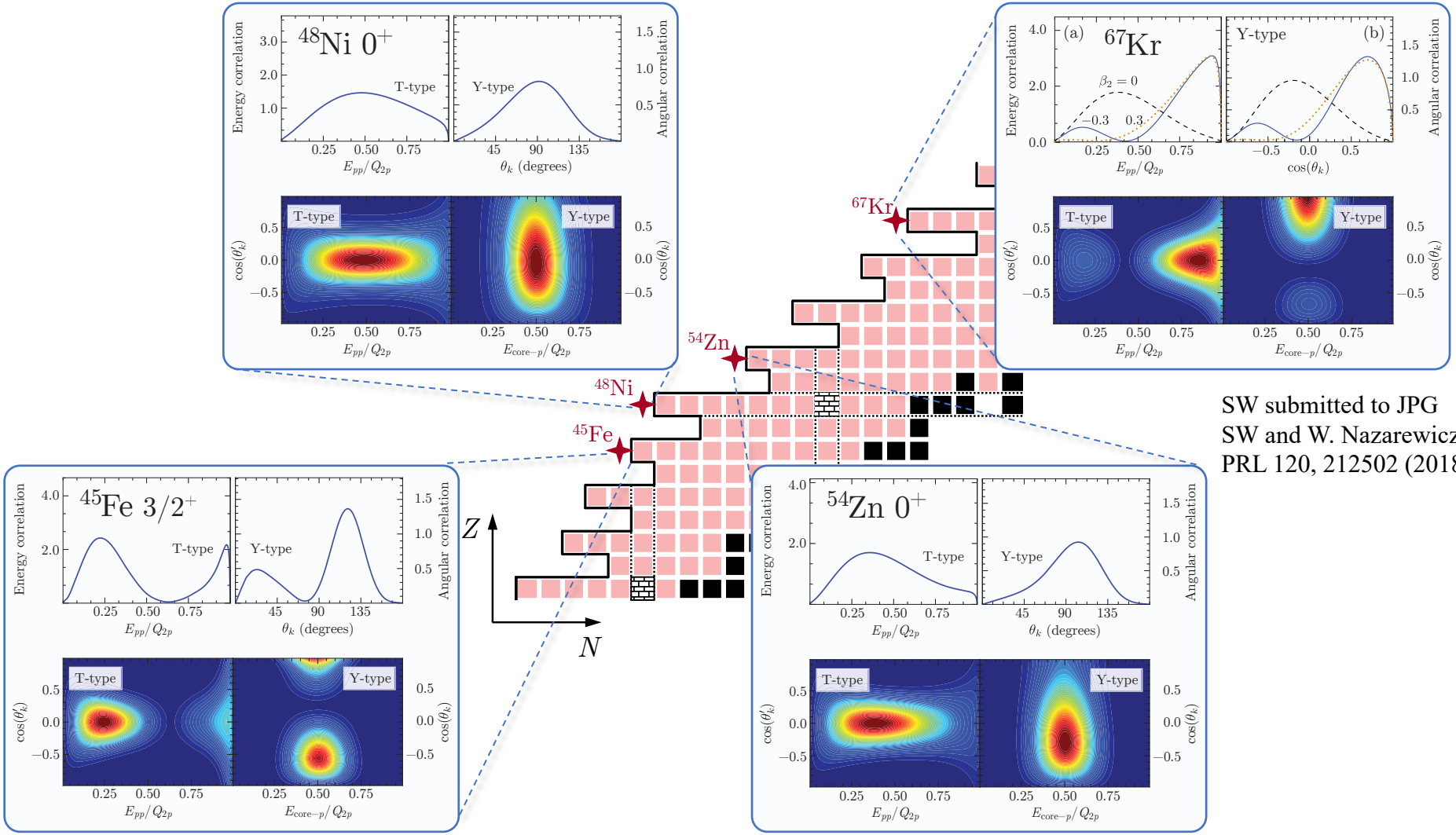


SW *et al.*, JPG 49, 10LT02 (2022)

T. Webb *et al.*, PRC 101, 044317 (2020)

- The correlation and updated spectrum suggest multiple states in the broad resonance of ^{11}O.

Perspectives: new data are anticipated



SW submitted to JPG
SW and W. Nazarewicz,
PRL 120, 212502 (2018)

Thank you for your attention!

Summary

- Continuum effects in open quantum systems
  - Complex radius
  - 2*p* decay
  - Nucleon-nucleon correlations
  - Connection between structure and decay properties

Acknowledgements

- Y. G. Ma
- Y. R. Lin
- Z. X. Shen
- I. Mukha
- L. G. Sobotka
- W. Nazarewicz
- Z. C. Xu
- M. Pfützner
- R. J. Charity
- A. Volya
- …



Thank you for your attention!

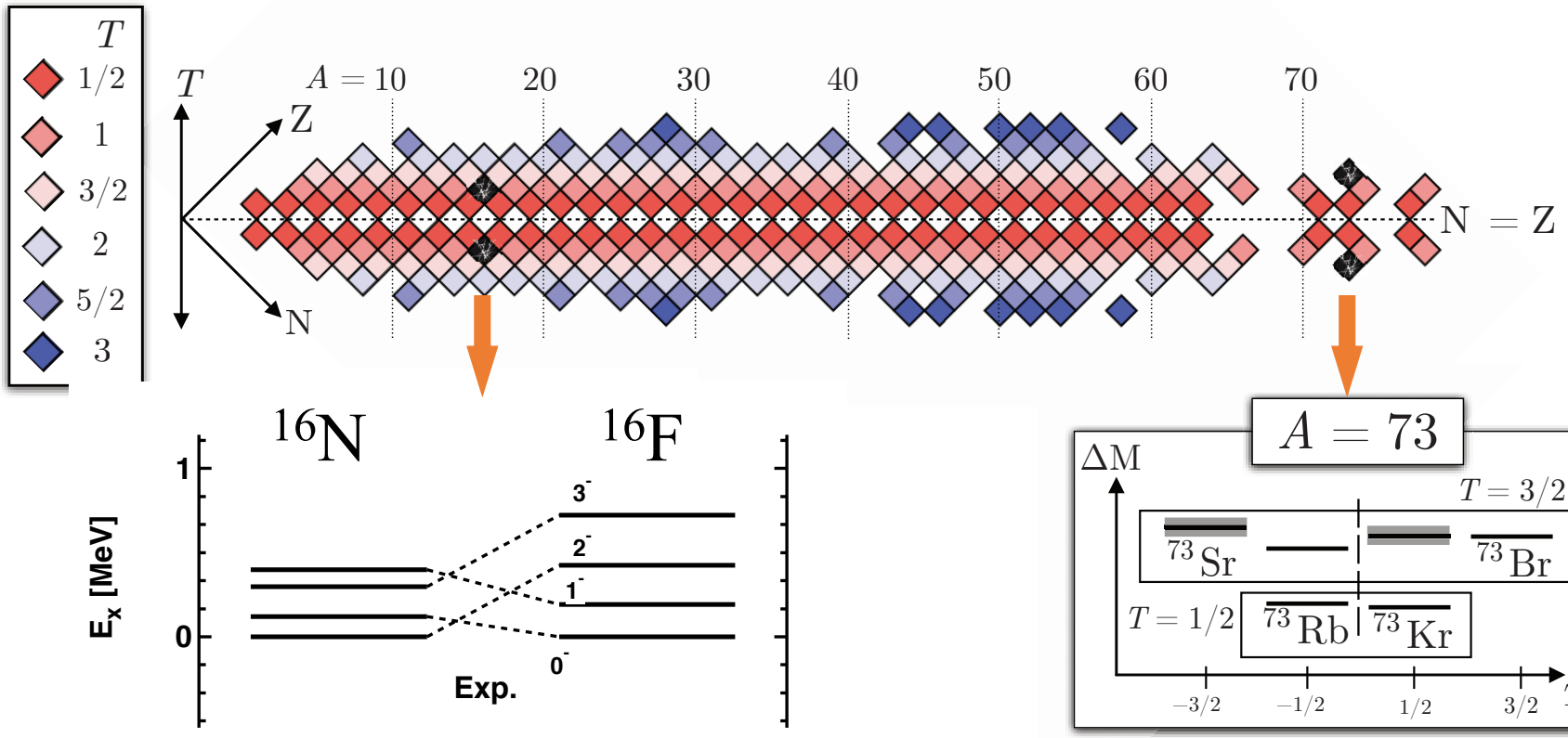
Questions

1. What's the difference between $2p$ and $2n$ decay?
2. Correlations evolutions during the decay process
3. Any simultaneous multi-particle emissions?
4. Does decay dynamics depends on the production?
5. Entanglement evolution during the decay



Backup

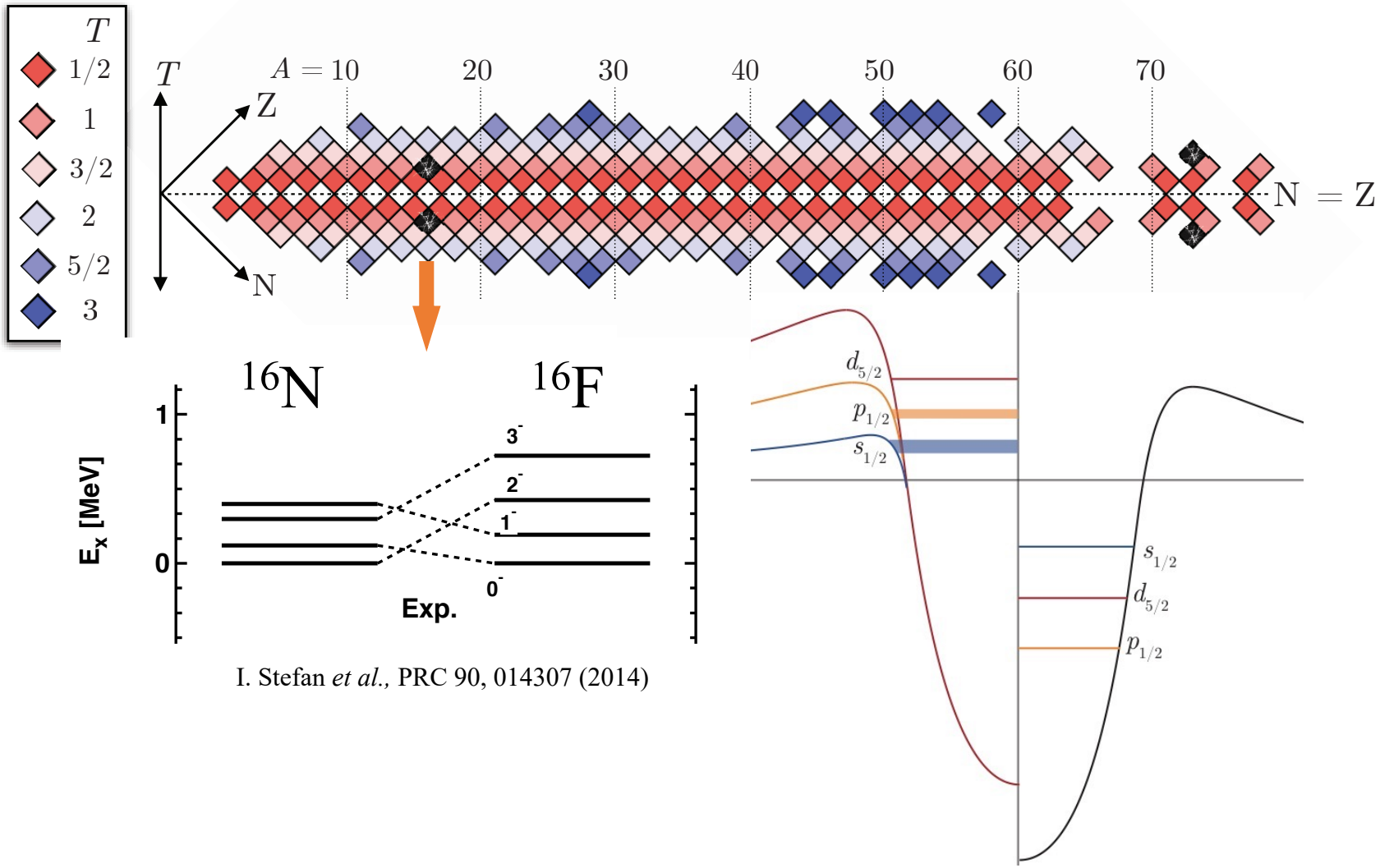
New-type island of inversion?



I. Stefan *et al.,* PRC 90, 014307 (2014)

D. Hoff, A. Rogers, SW *et al.,* Nature 580, 52 (2020)

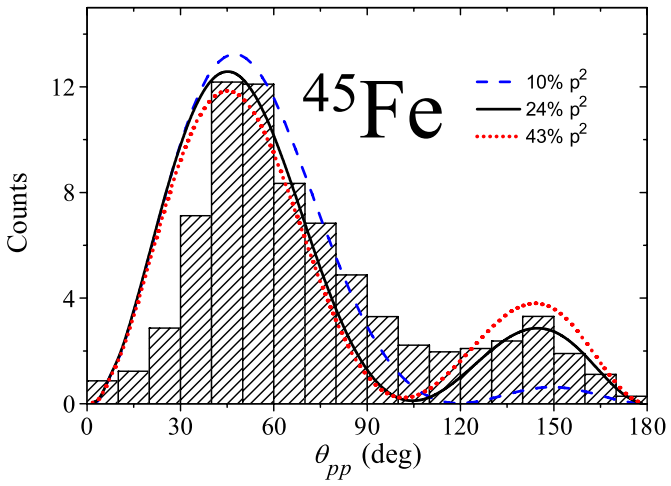
New-type island of inversion?



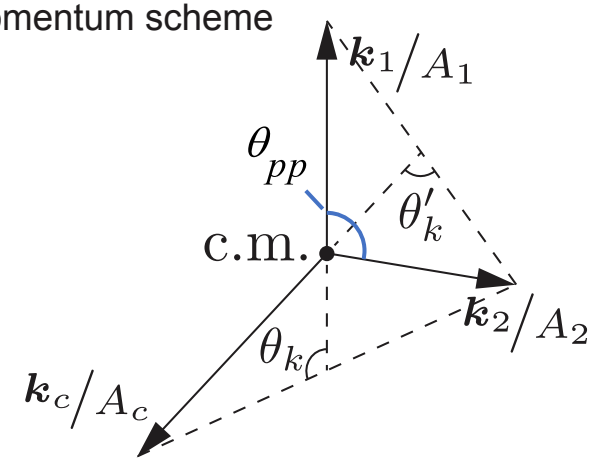
I. Stefan *et al.*, PRC 90, 014307 (2014)

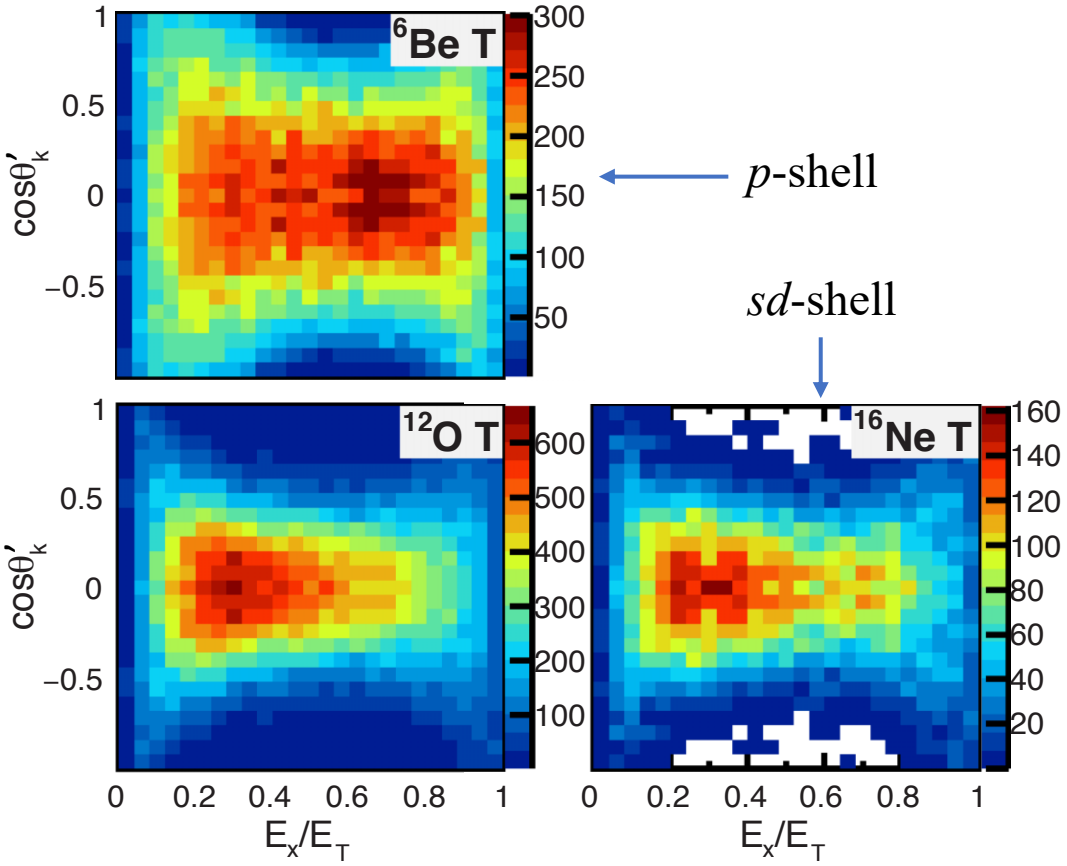
Asymptotic nucleon-nucleon correlation

K. Miernik *et al.* PRL 99, 192501 (2007)



Momentum scheme



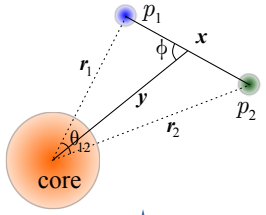


T.B. Webb *et al.* Phys. Rev. C 100, 024306 (2019)

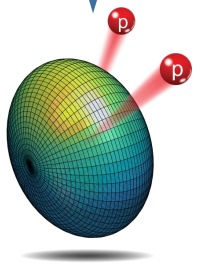
Selected progresses in multi-*p* decay

GCC model

SW, Michel, Nazarewicz *et al.*
PRC 122, 122501 (2017)



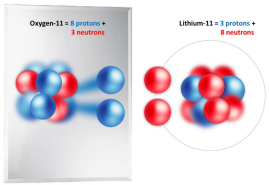
Deformed 2*p*



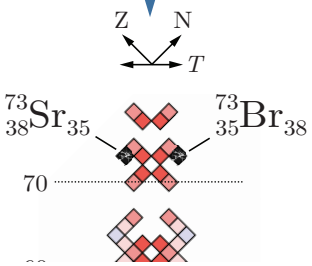
SW and Nazarewicz
PRL 120, 212502 (2018)

2*p* emitter ^{11}O

Webb, SW, Brown *et al.*
PRL 122, 122501 (2019)



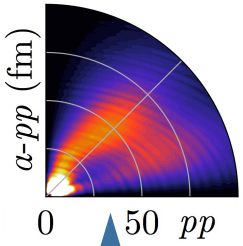
Mirror symmetry



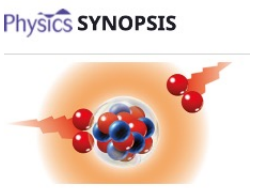
Hoff, Rogers, SW *et al.*
Nature 580, 52 (2020)

2*p* dynamics

SW and Nazarewicz
PRL 126, 142501 (2021)



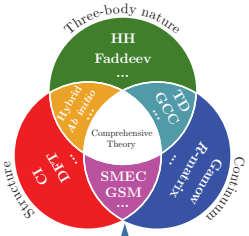
4*p* emitter ^{18}Mg



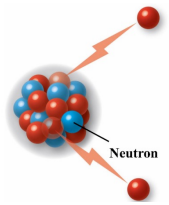
Jin, Niu, Brown, Li *et al.*
PRL 127, 262502 (2021)

2*p* Review

Pfützner, Mukha, SW *et al.*
PPNP 132, 104050 (2023)



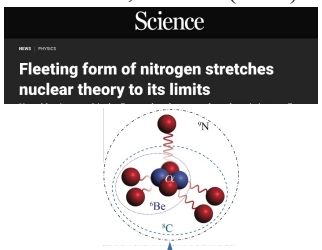
β-delayed 2*p*



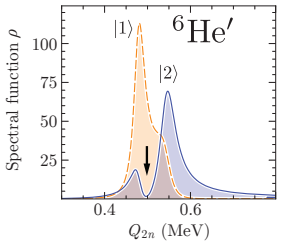
Liu, Xu, Sun, Yuan *et al.*
PRL 129, 242502 (2022)

5*p* emitter ^{9}N

Charity, Wylie, SW *et al.*
PRL 131, 172501 (2023)



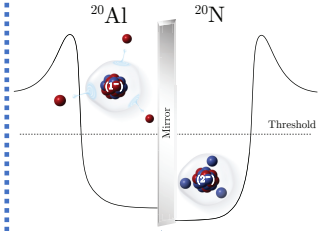
Non-exp decay



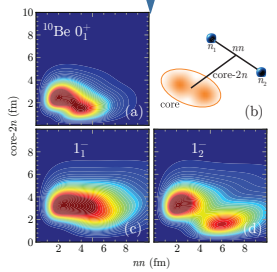
SW, Nazarewicz, Ma
PRR 5, 023183 (2023)

3*p* emitter ^{20}Al

Xu, Mukha, Li, SW *et al.*
PRL 135, 022502 (2025)



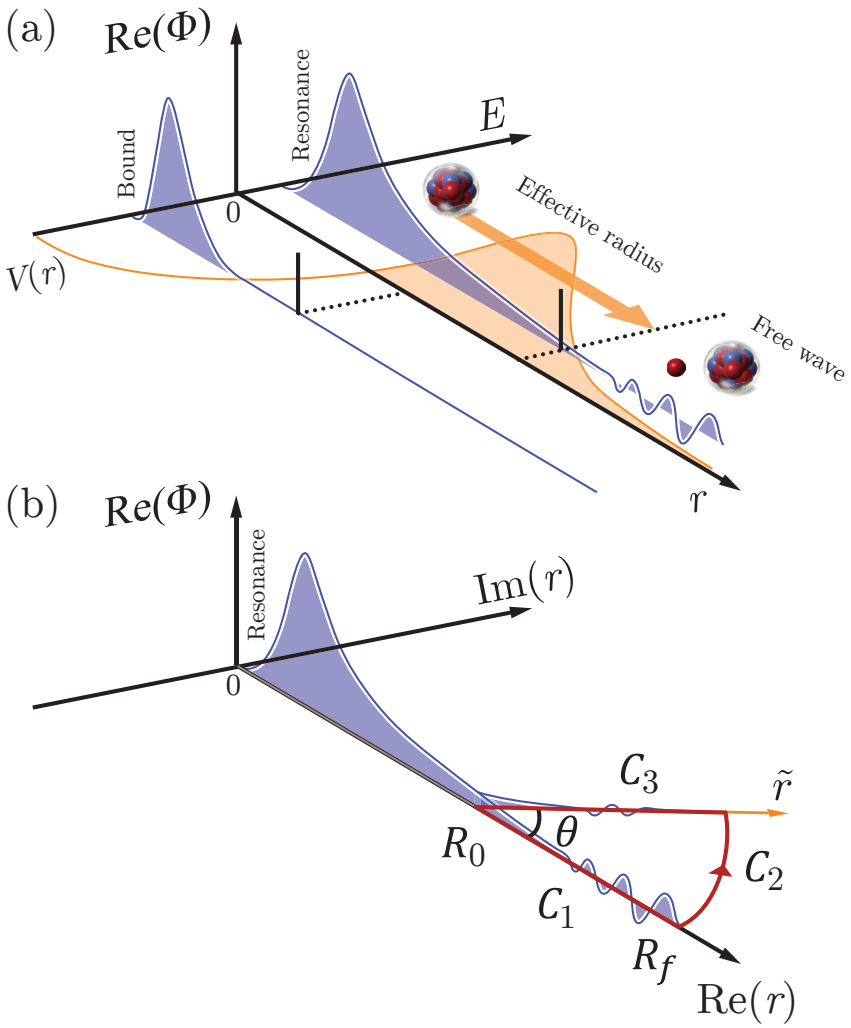
Threshold 1$^-$

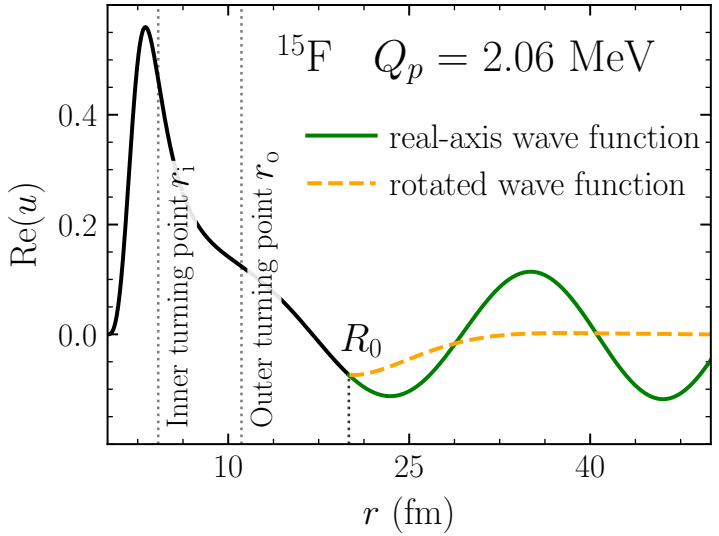


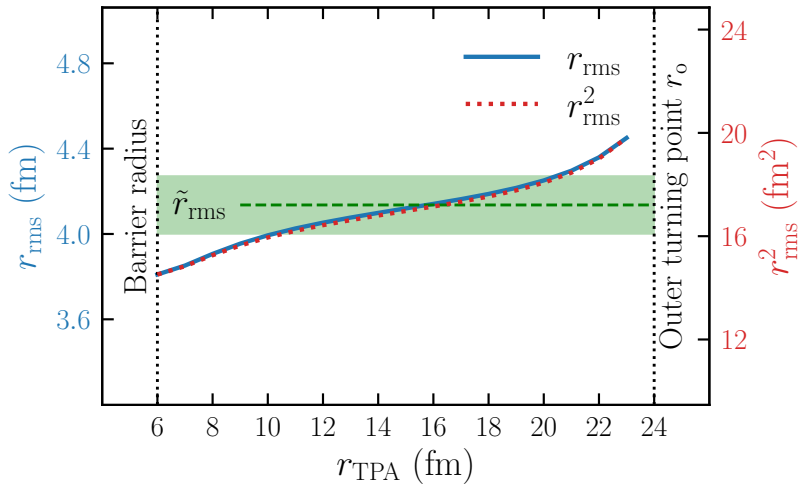
Chen, Ayyad, Bazin *et al.*
PRL 134, 012502 (2025)

2017 2018 2019 2020 2021 2022 2023 2024 2025 2026

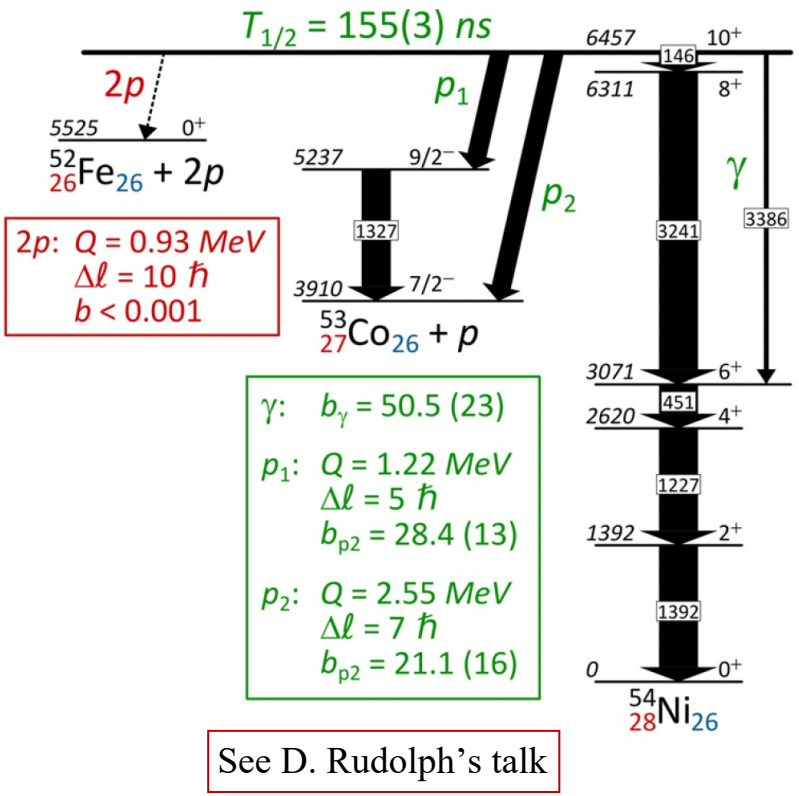
Complex radii of particle emitters



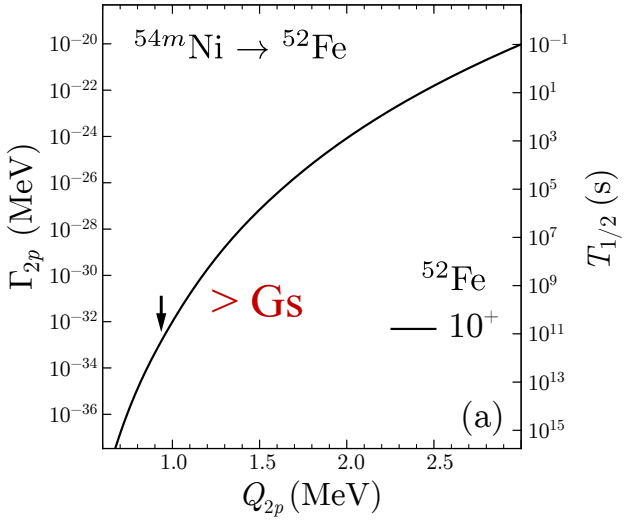


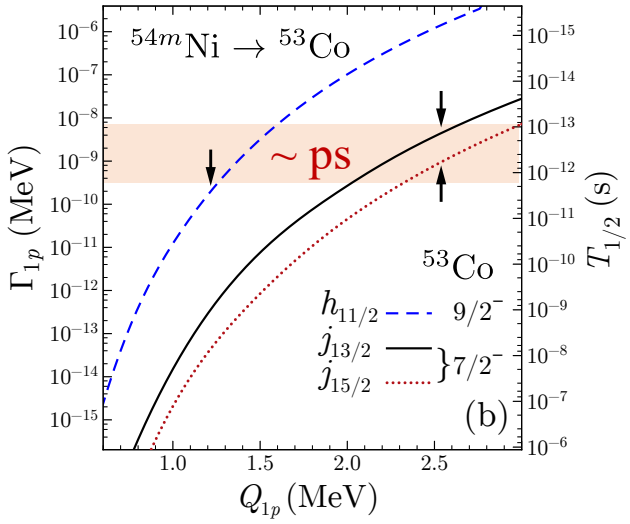


Decay property of ^{54m}Ni



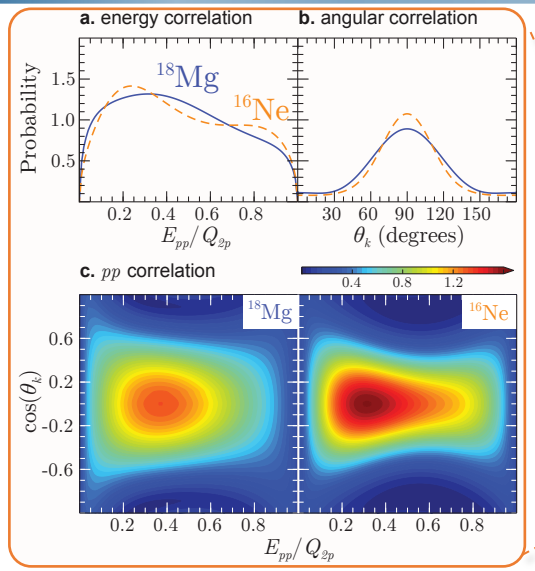
J. Giovinazzo *et al.*, Nat. Comm. 12, 4805 (2021)

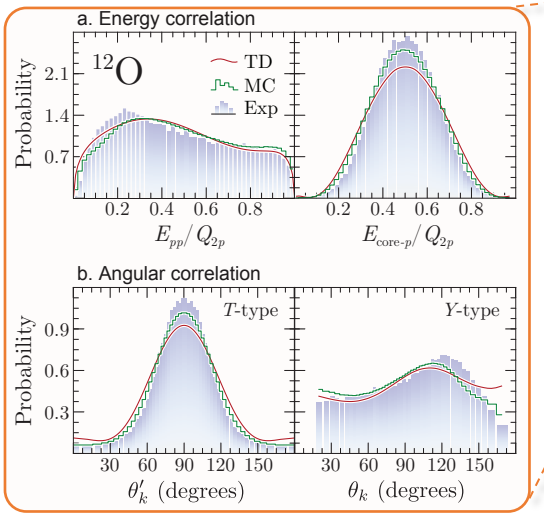


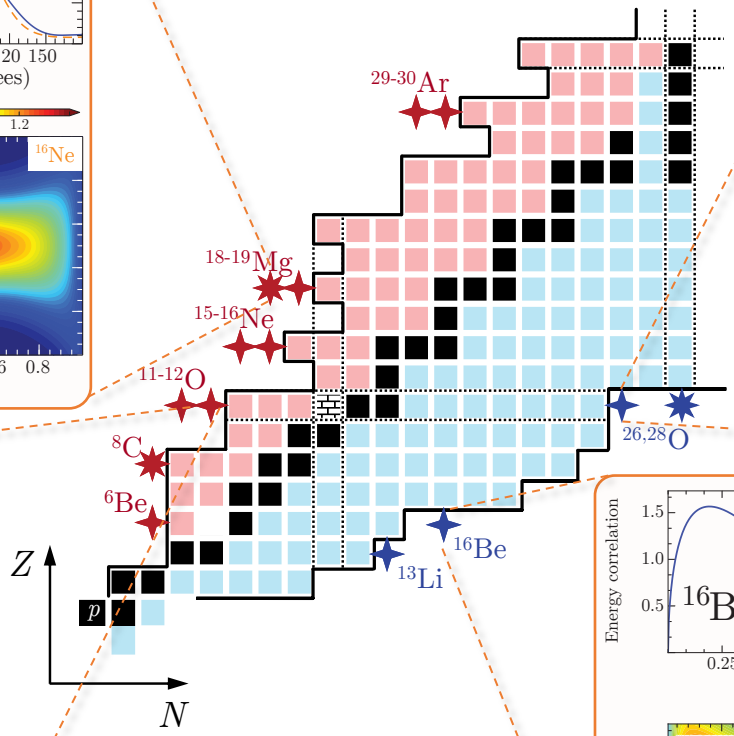


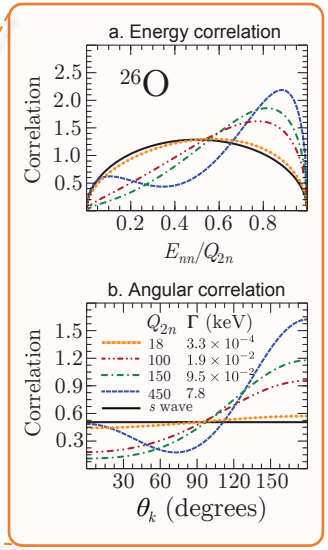
- Lifetime strongly depends on the decay energy and channels.
- Branching ratio is less than 10^{-21} for 2*p* decay.

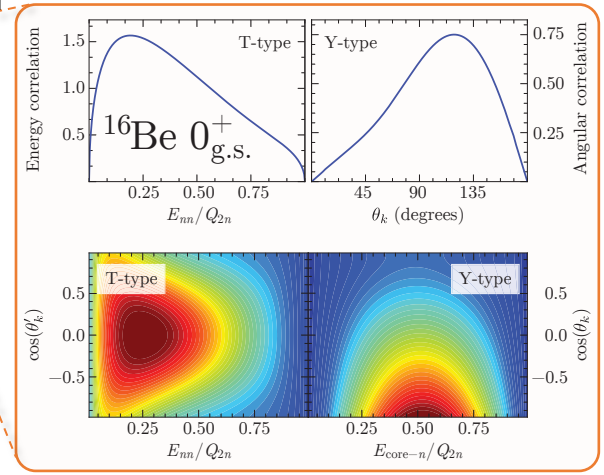
Correlations of light-mass nuclei



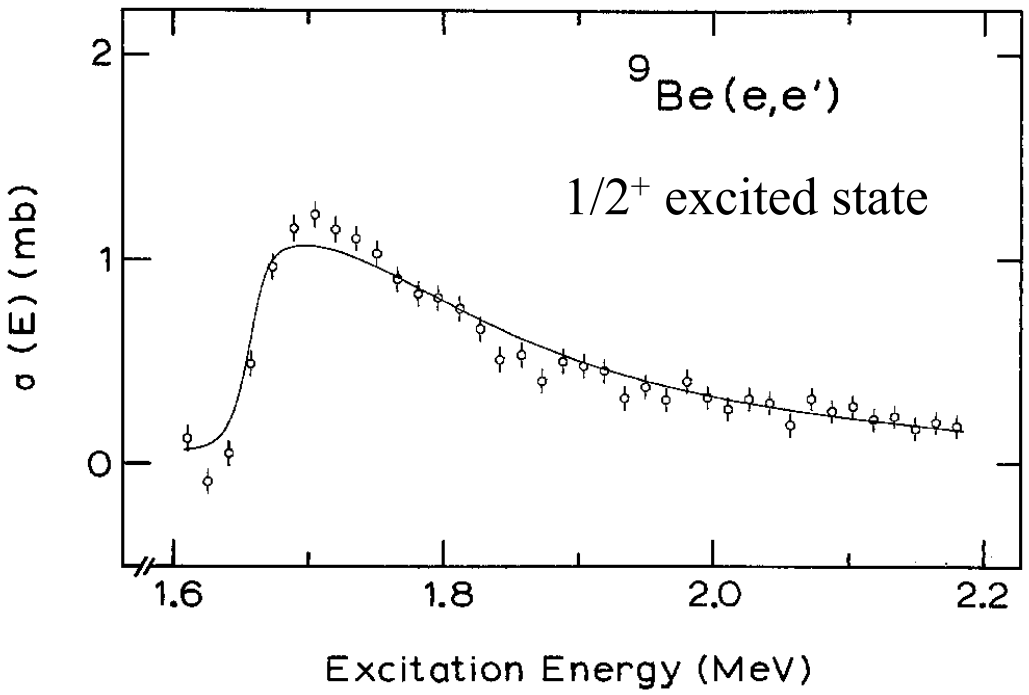




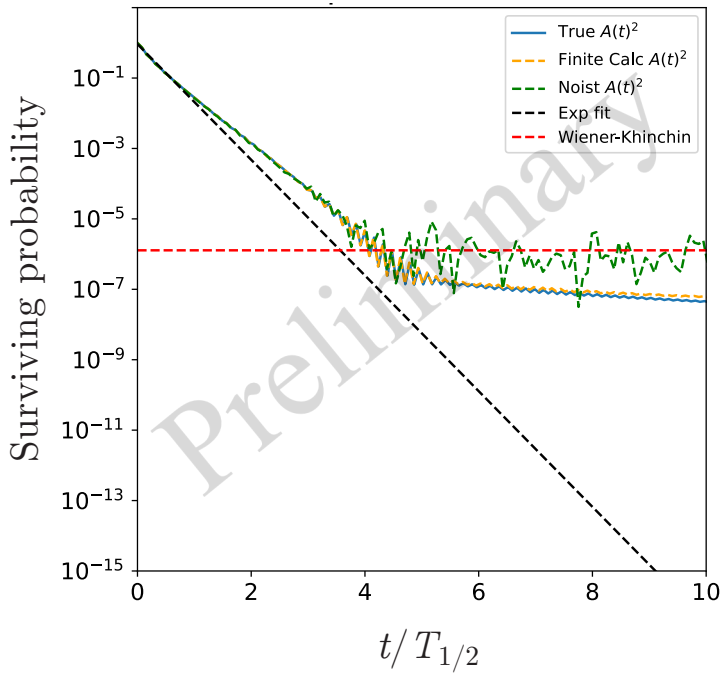




Experimental candidate

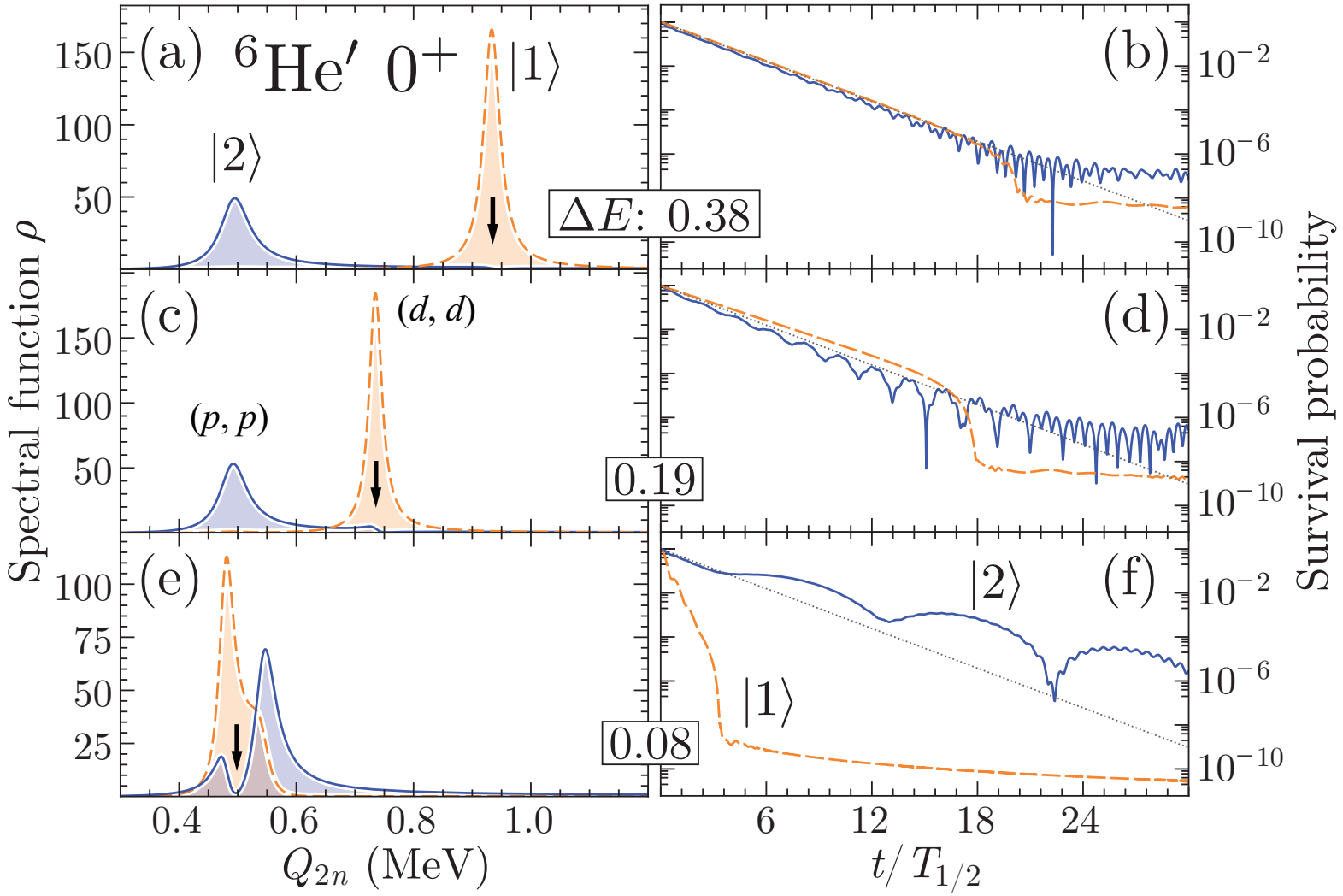


G. Kuechler *et al.*, Z. Phys. A 326, 447454 (1987)

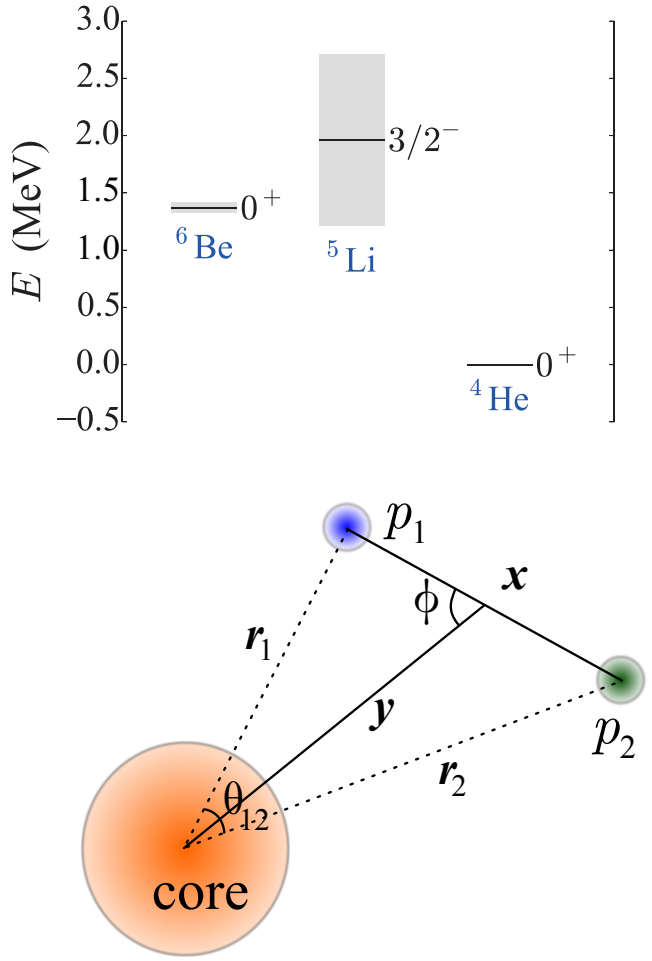


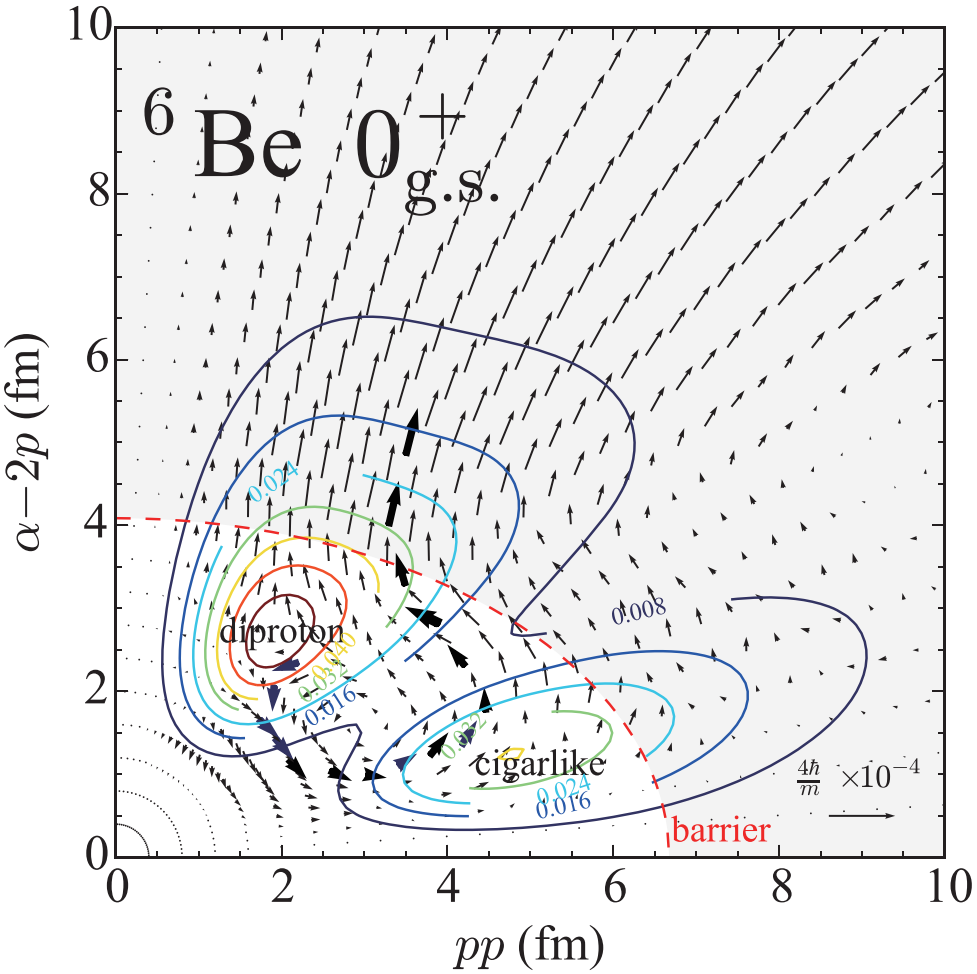
- Non-exponential decay can be studied through the asymmetric spectral function
- High resolution data are anticipated

Near-lying resonances with the same spin



Ground-state of ^{6}Be

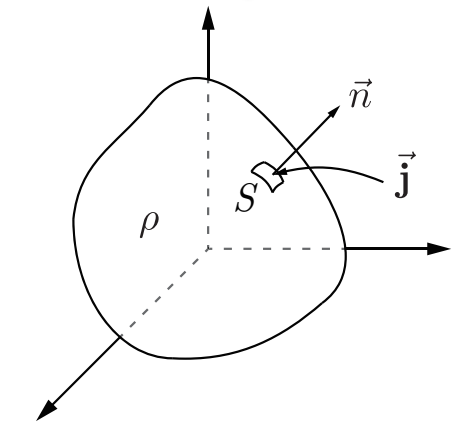




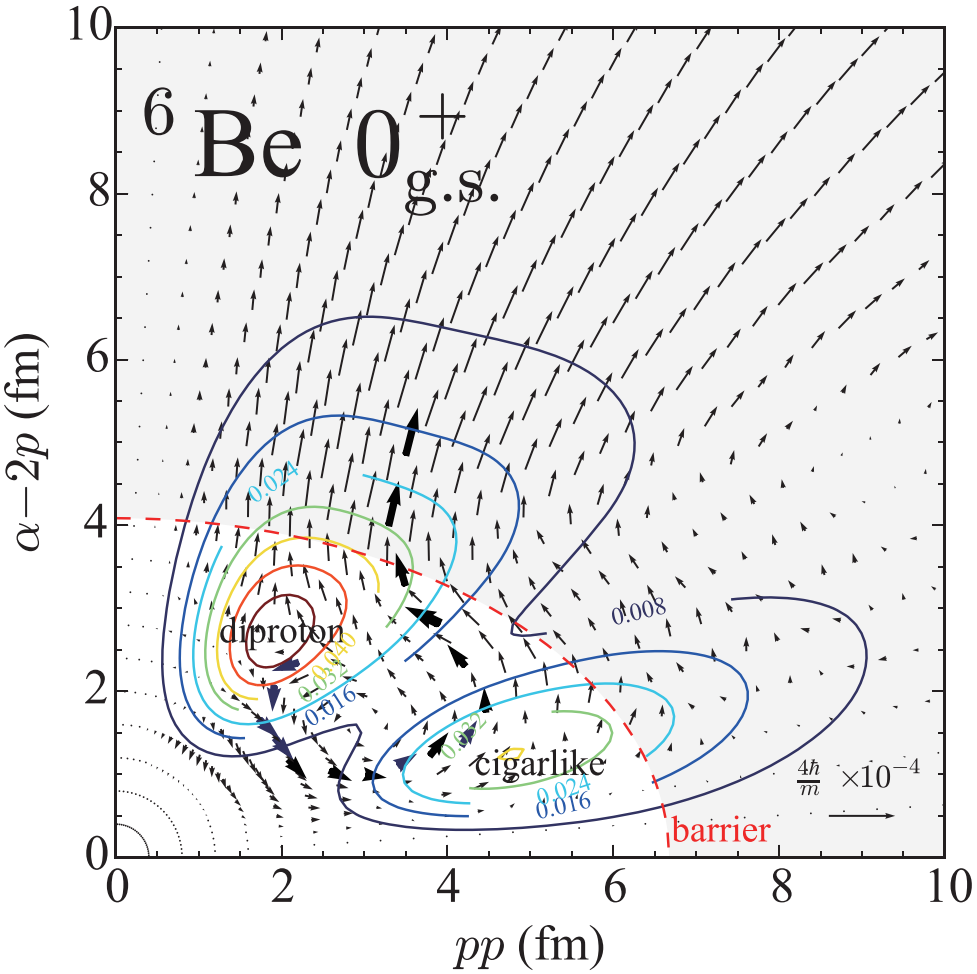
SW *et al.*, Phys. Rev. C 99, 054302 (2019)

Ground-state of ^{6}Be

Probability current

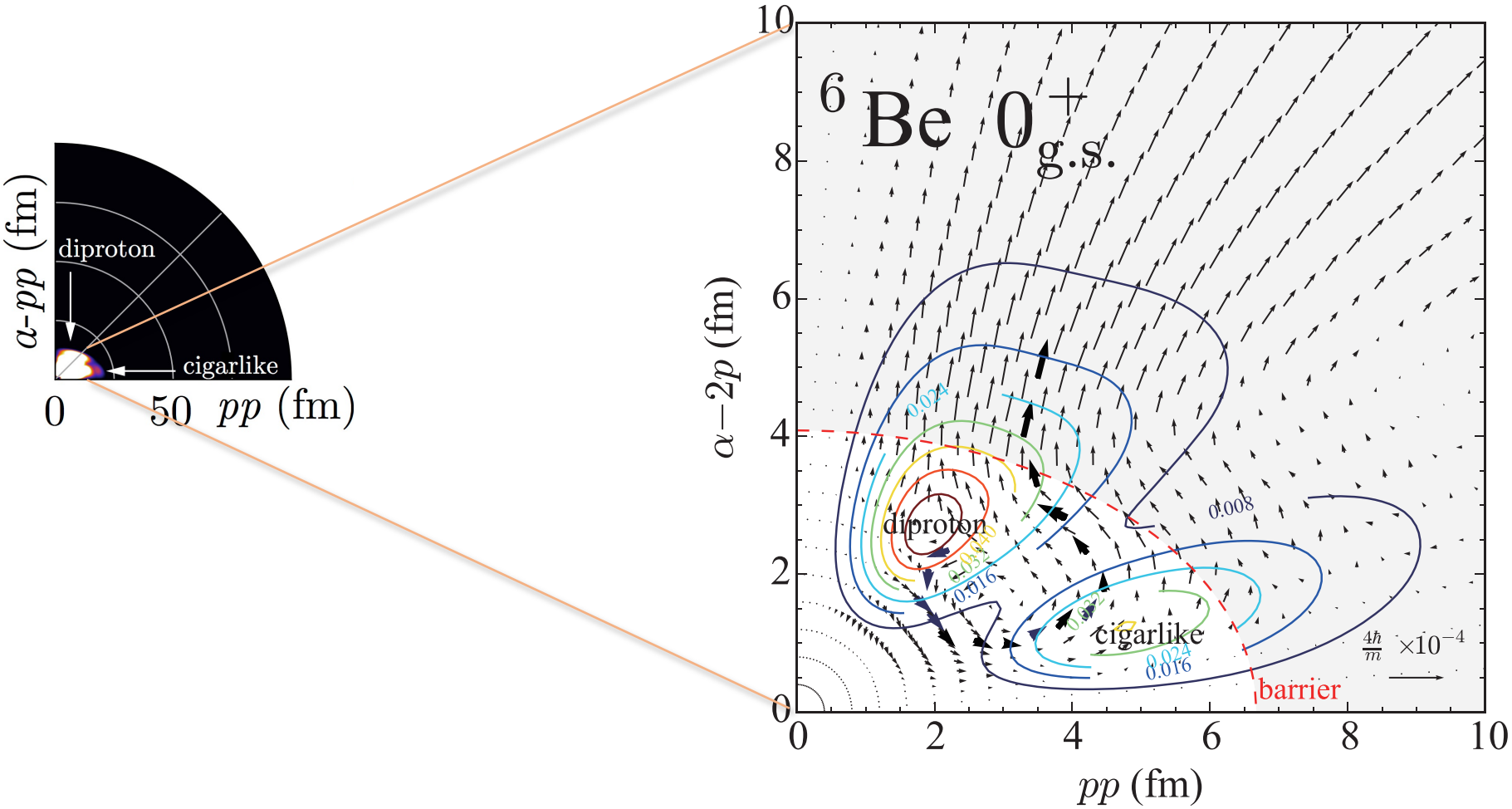


$$\iiint \frac{\partial \rho}{\partial t}\,\mathrm{d}V = -\oiint \vec{\mathbf{j}}\cdot\vec{n}\,\mathrm{d}S$$



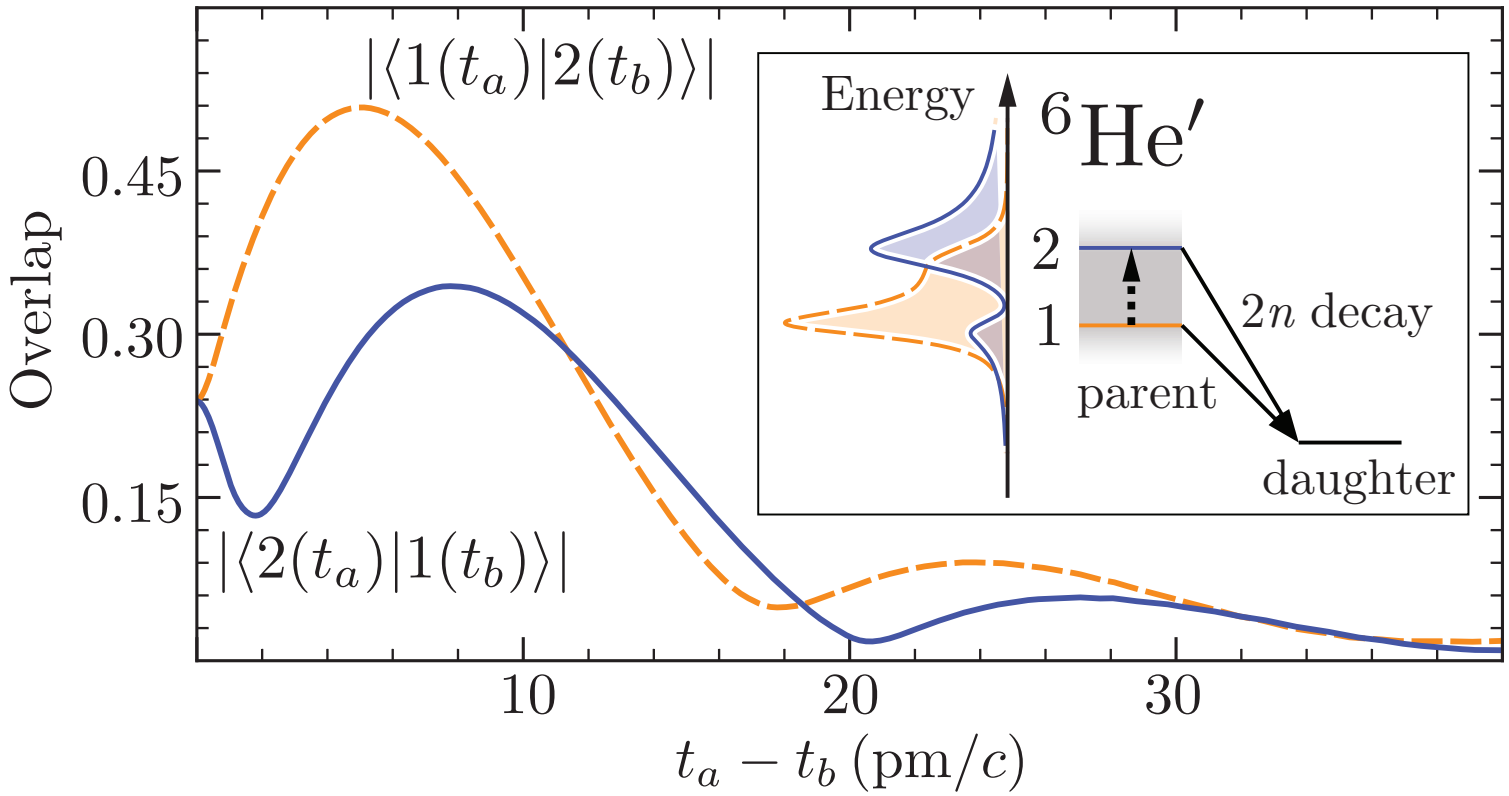
SW *et al.*, Phys. Rev. C 99, 054302 (2019)

Ground-state of ^{6}Be



SW *et al.*, Phys. Rev. C 99, 054302 (2019)

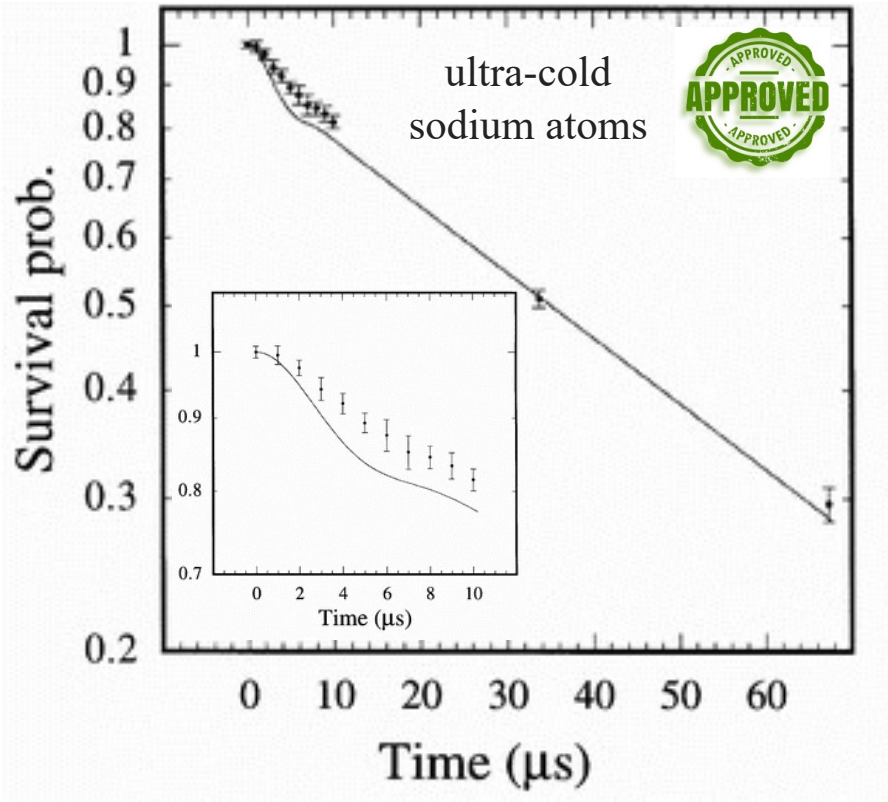
Virtual transition



SW, W. Nazarewicz, A. Volya, and Y.G. Ma, Phys. Rev. Res. 5, 023183 (2023)

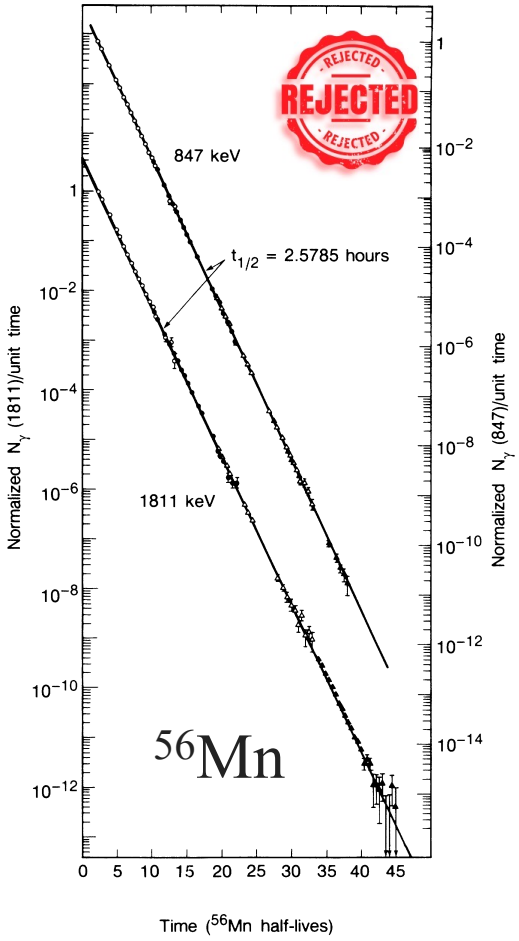
Probe non-exponential decay experimentally

Initial stage



S. R. Wilkinson *et al.*, Nature 387, 575 (1997)

Long-time period

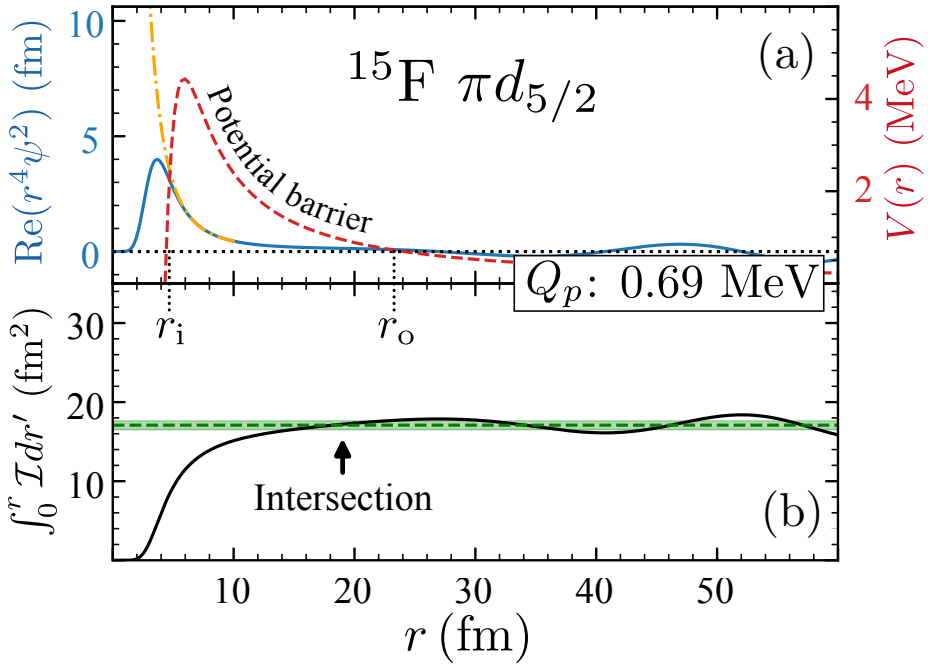


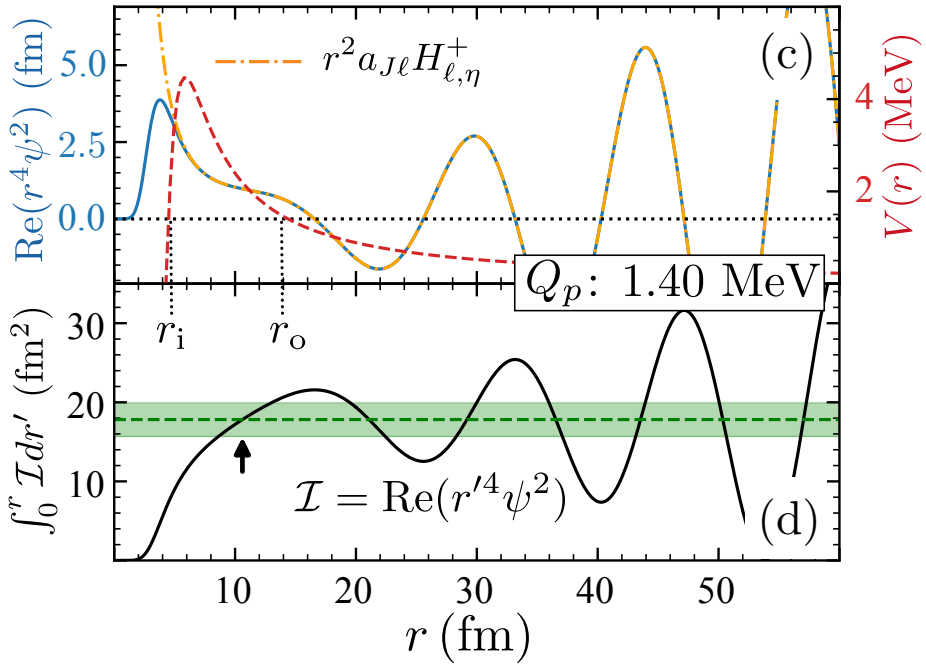
E. B. Norman *et al.*, Phys. Rev. Lett. 60, 2246 (1988)

The objective of this work is to offer experimentally accessible scenarios to probe post-exponential decay.

Complex radius of 1*p* emitter ^{15}F

Wavefunction & radius integrand at Q = 0.69, 1.40 MeV



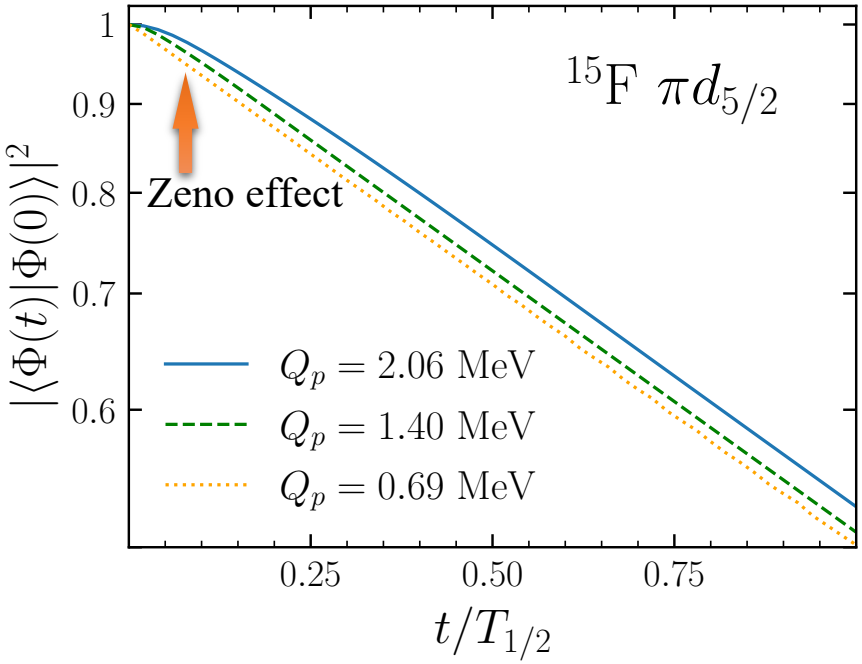


Y. R. Lin, SW *et al.*, Arxiv 2511.10238 (2025)

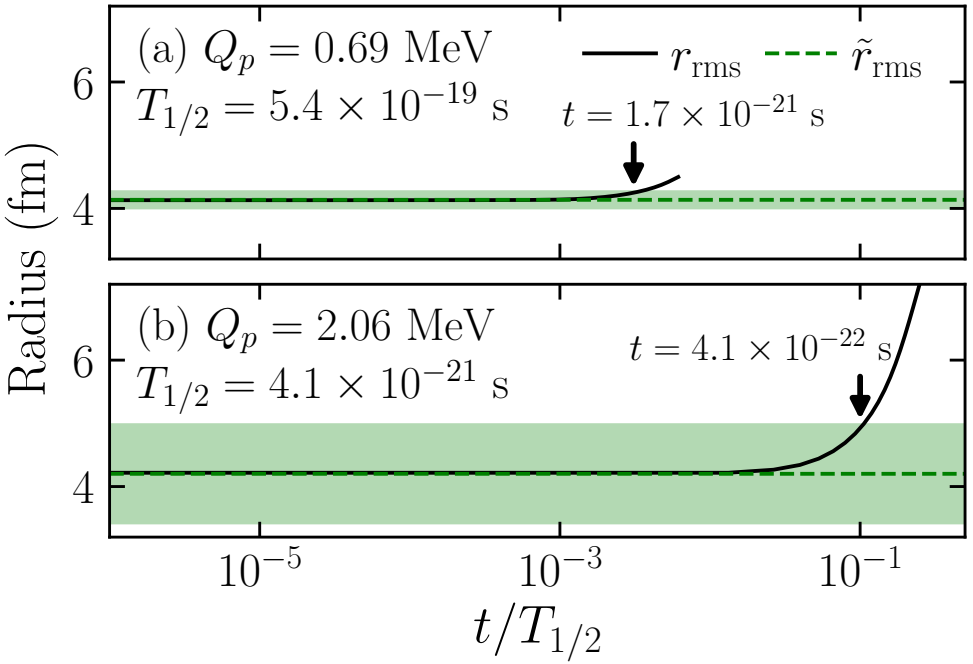
- The contribution to the complex radius from the asymptotic region is largely canceled out.
- The match point for the complex radius is located inside the barrier.

RMS radius evolution during the decay

Survival probability



Radius evolution at Q = 0.69, 2.06 MeV

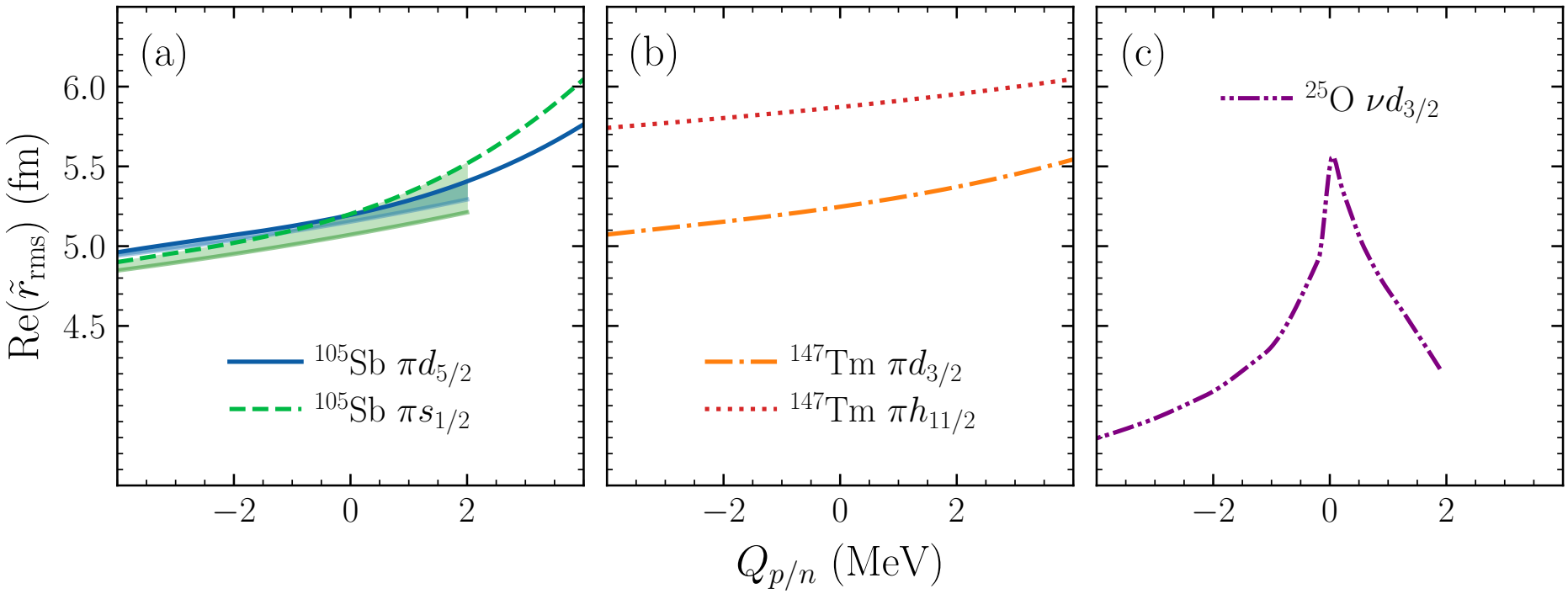


Y. R. Lin, SW *et al.*, Arxiv 2511.10238 (2025)

- Initially, the rms radius matches with the complex one.
- There is a plateau for the rms radius at the early stage of the decay due to the quantum Zeno effect.
- For long-lived system, one can extract the radius experimentally.

Radius enhancement around the dripline

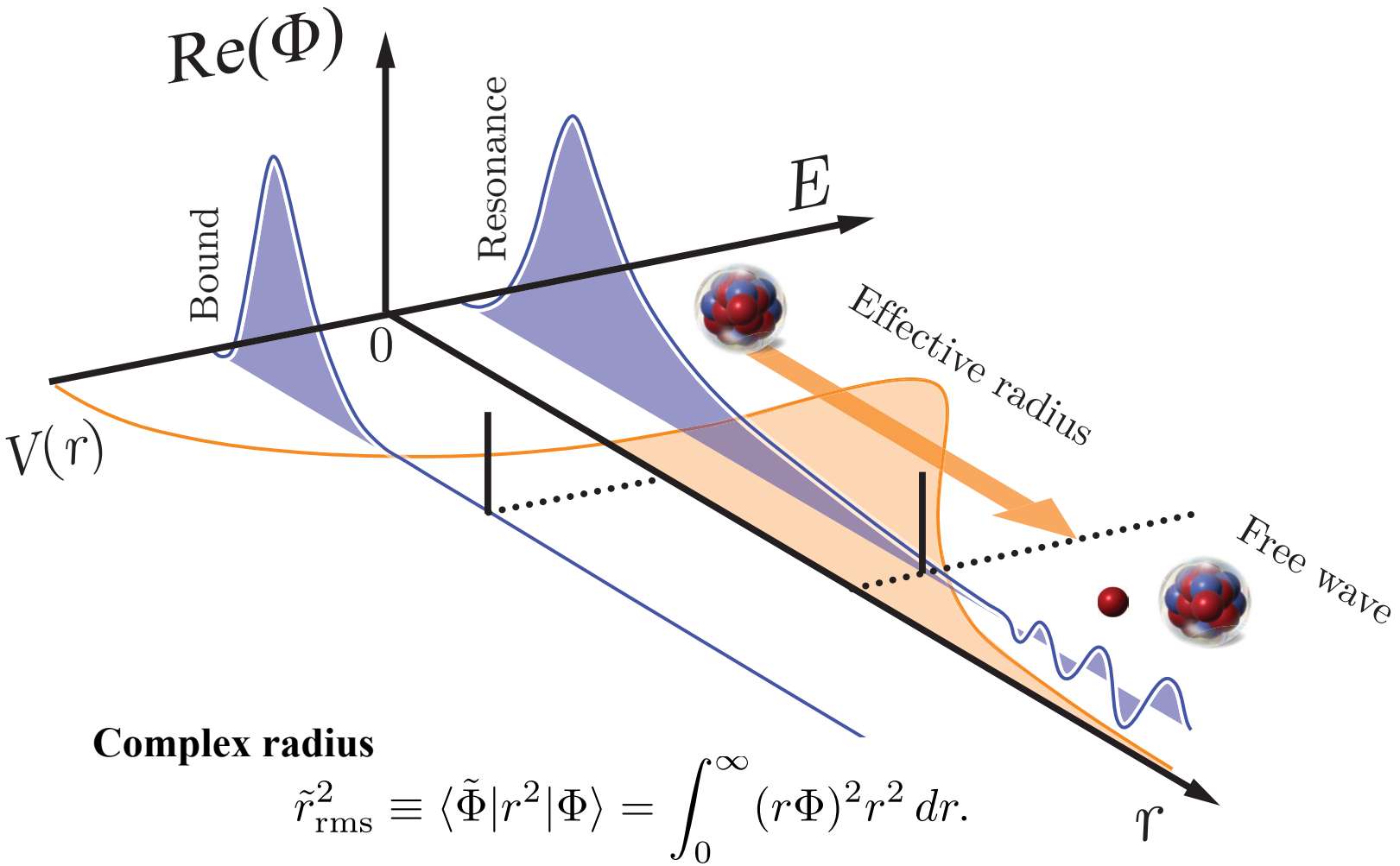
Radius predictions for ^{105}Sb, ^{147}Tm, and ^{25}O



Future test with laser spectroscopy?

- The radii of all the dripline systems are enhanced by the continuum.
- Neutron-rich nuclei are more sensitive to the continuum.

Complex radii of particle emitters

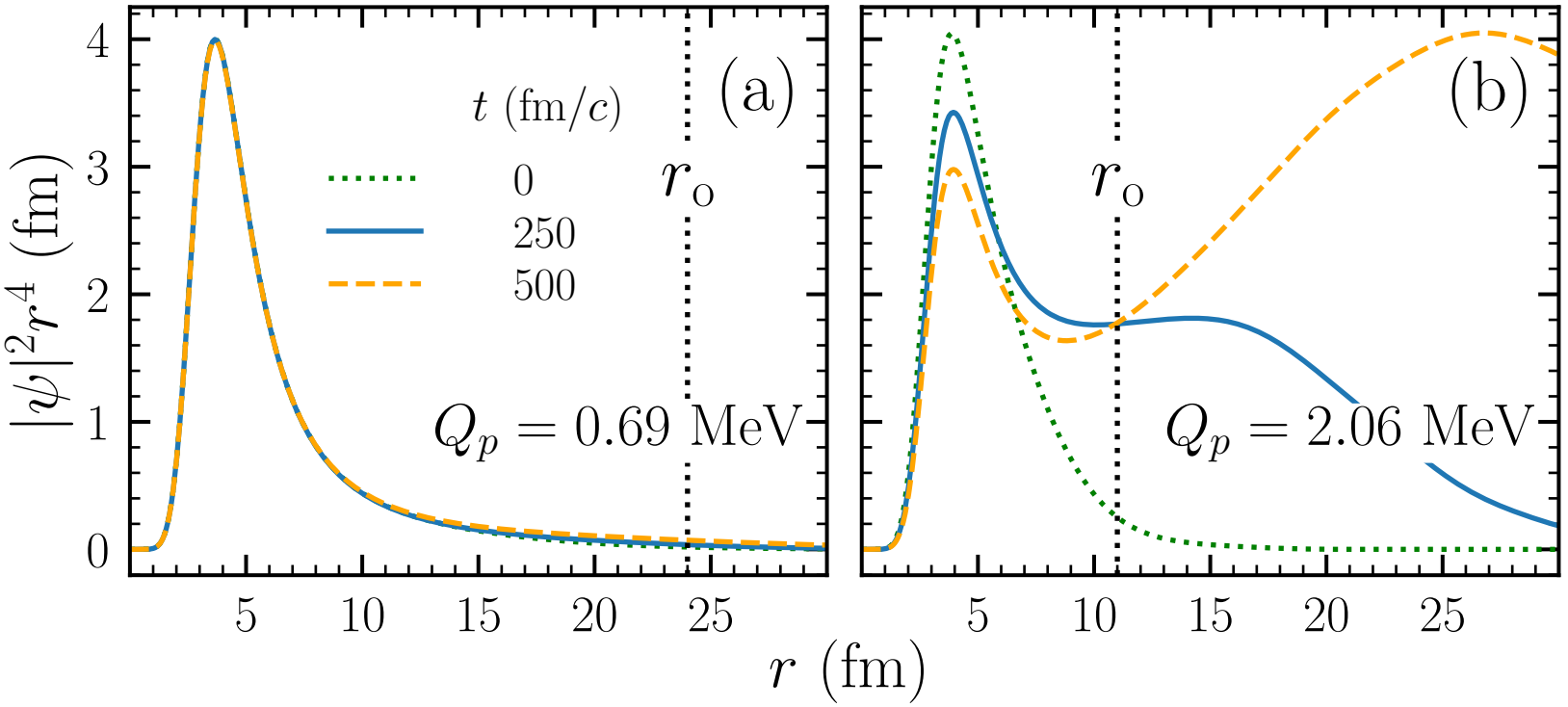


Complex radius

$$\tilde{r}^2_{\rm rms} \equiv \langle \tilde{\Phi} | r^2 | \Phi \rangle = \int_0^\infty (r\Phi)^2 r^2 \, dr.$$

RMS radius evolution during the decay

Wavefunction evolution at Q = 0.69, 2.06 MeV

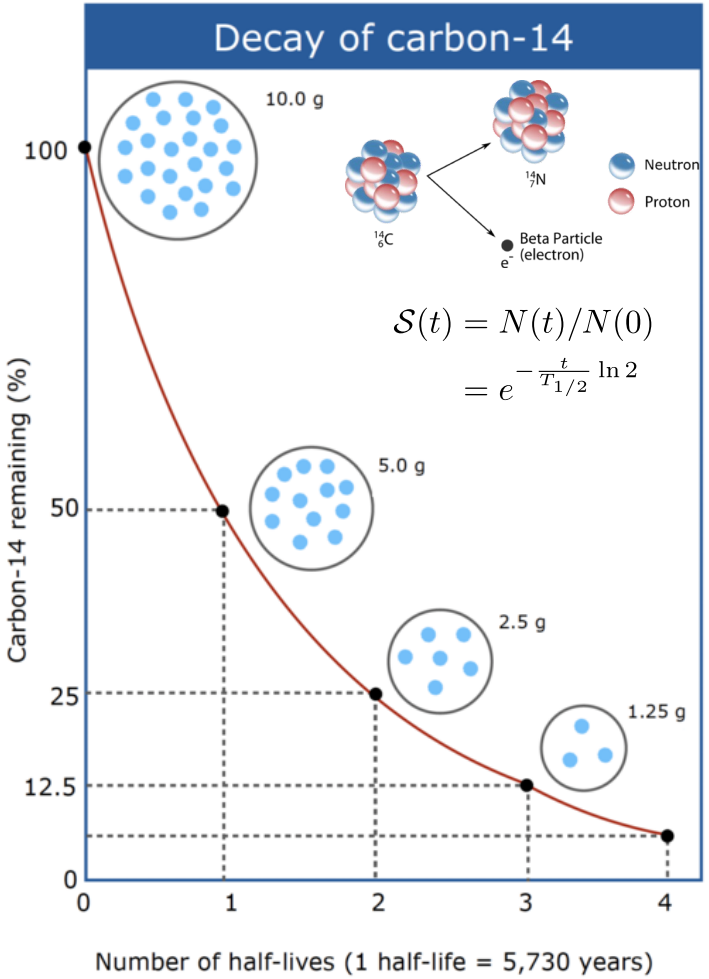


- The density inside r_i gradually decreases.
- Beyond r_o is the free space for particle emission.

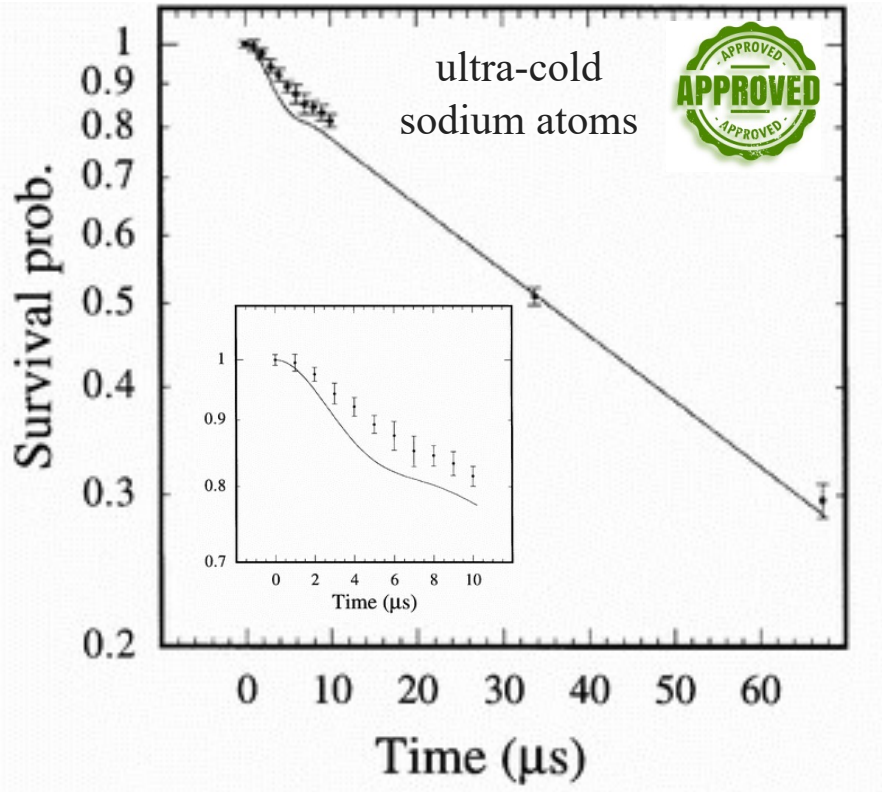
Y. R. Lin, SW *et al.*, Arxiv 2511.10238 (2025)

Quantum Zeno effect

Classical picture of decay



Quantum tunneling

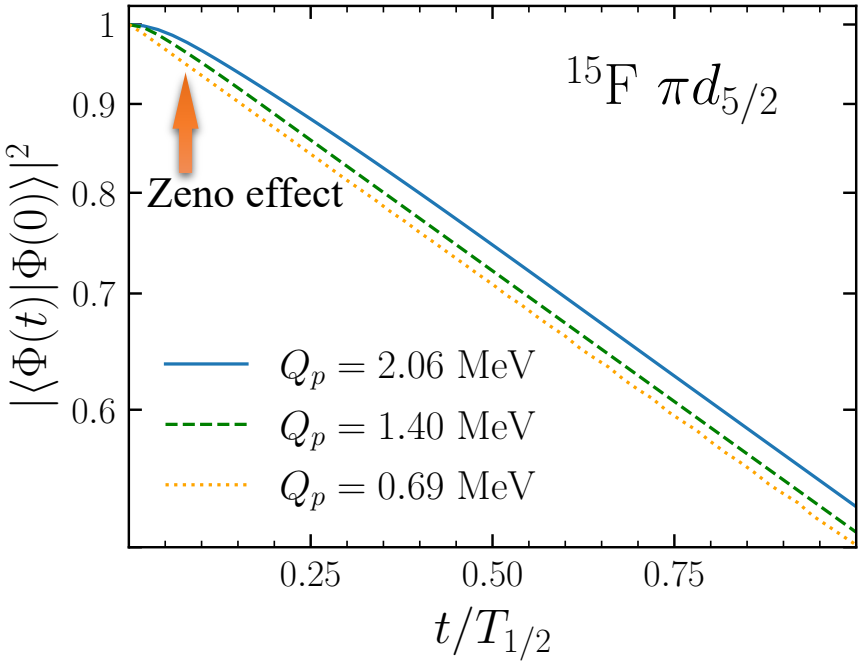


S. R. Wilkinson *et al.*, Nature 387, 575 (1997)
M. Ji and C. Xu, Chinese Phys. Lett. 38 032301 (2021)

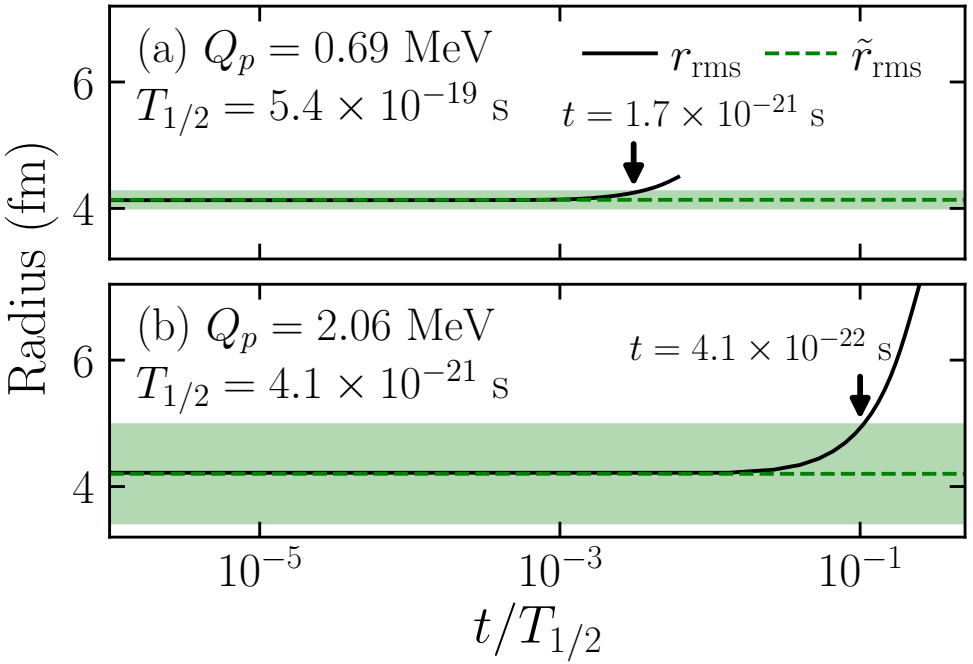
- Decay rate is a constant in classical decay.
- Memory effect in quantum decay.

RMS radius evolution during the decay

Survival probability



Radius evolution at Q = 0.69, 2.06 MeV

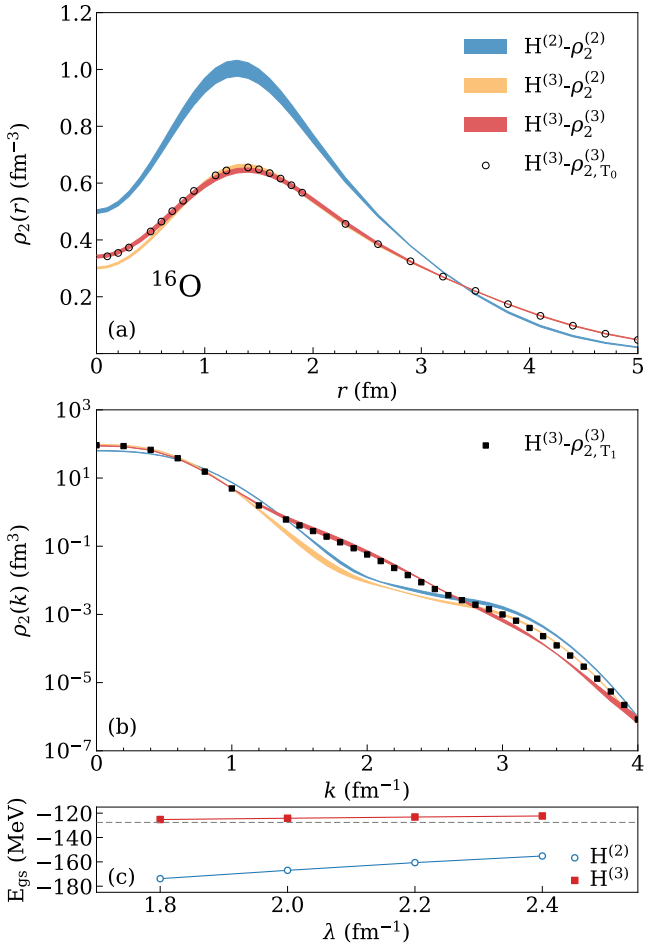


Y. R. Lin, SW *et al.*, Arxiv 2511.10238 (2025)

- Initially, the rms radius matches with the complex one.
- There is a plateau for the rms radius at the early stage of the decay due to the quantum Zeno effect.
- For long-lived system, one can extract the radius experimentally.

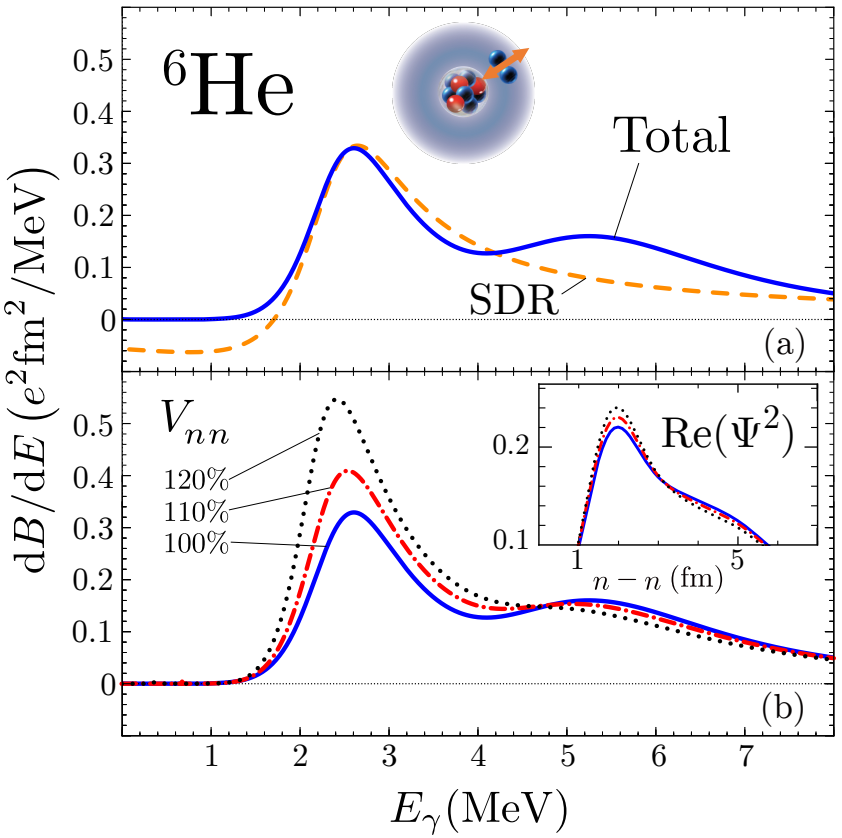
Short & mid ⟷ long range correlations

3-body effect on short-range correlation



H. Y. Shang *et al.*, in preparation

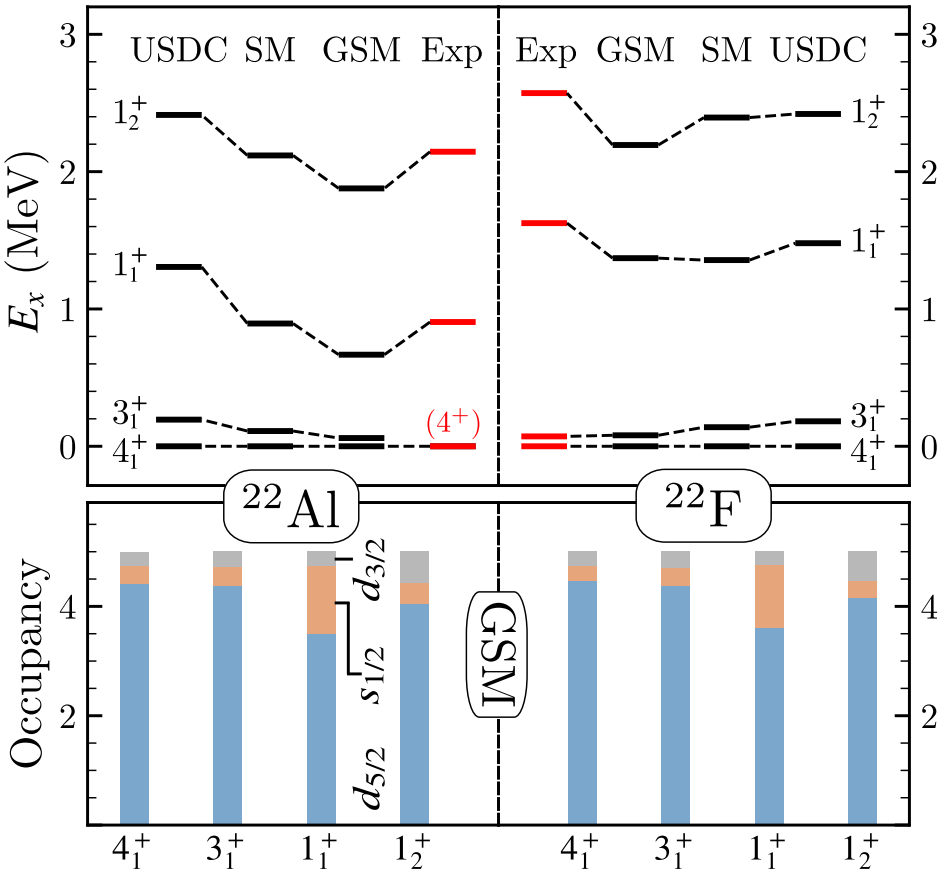
*E*1 response



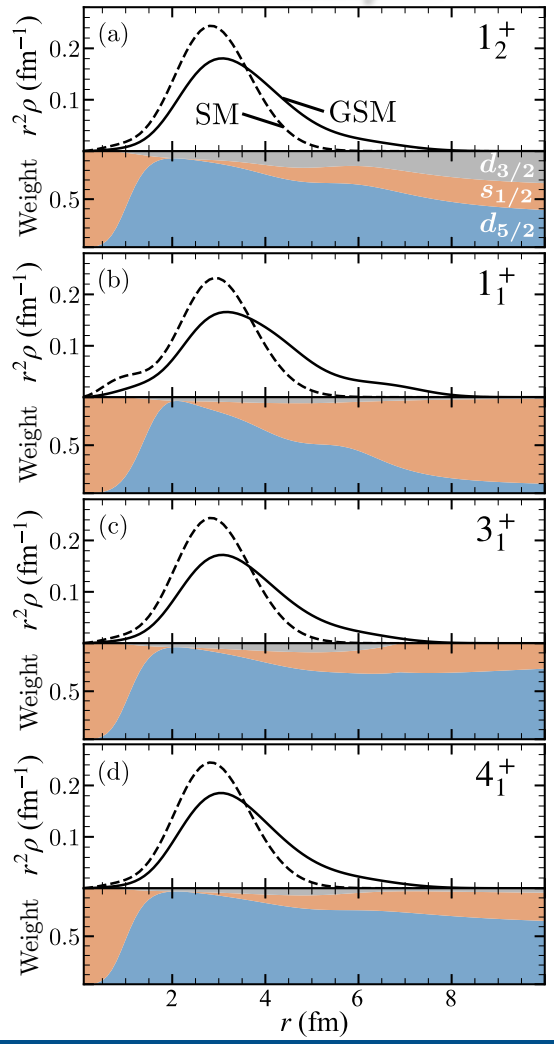
Y. H. Yang *et al.*, Eur. Phys. J. A
T. Nakamura *et al.*, Phys. Rev. Lett 96, 252502(2006)
Y. L. Sun *et al.*, Phys. Lett. B 814, 136072

Halo structure in ^{22}Al?

Spectroscopy of ^{22}Al and ^{22}F

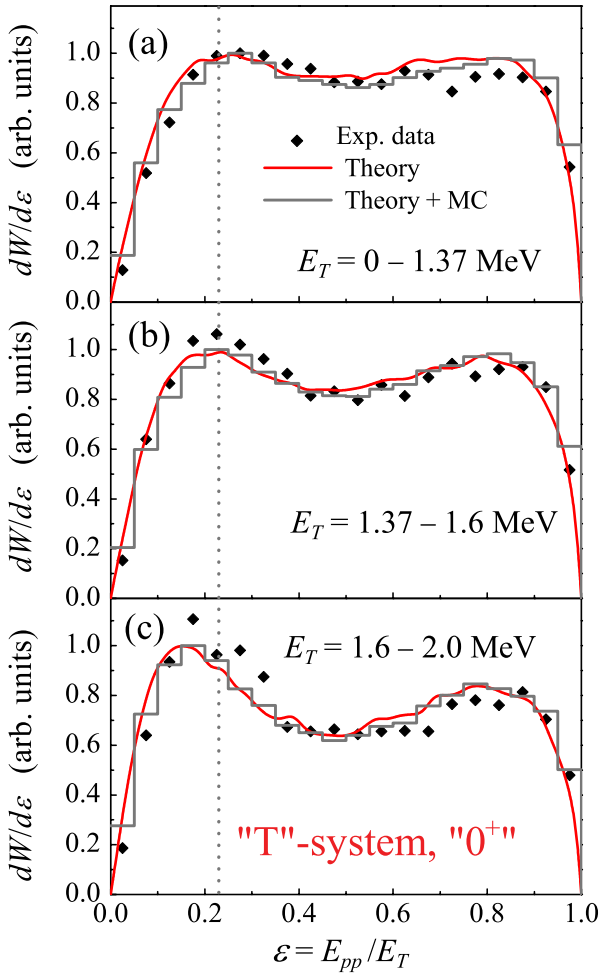


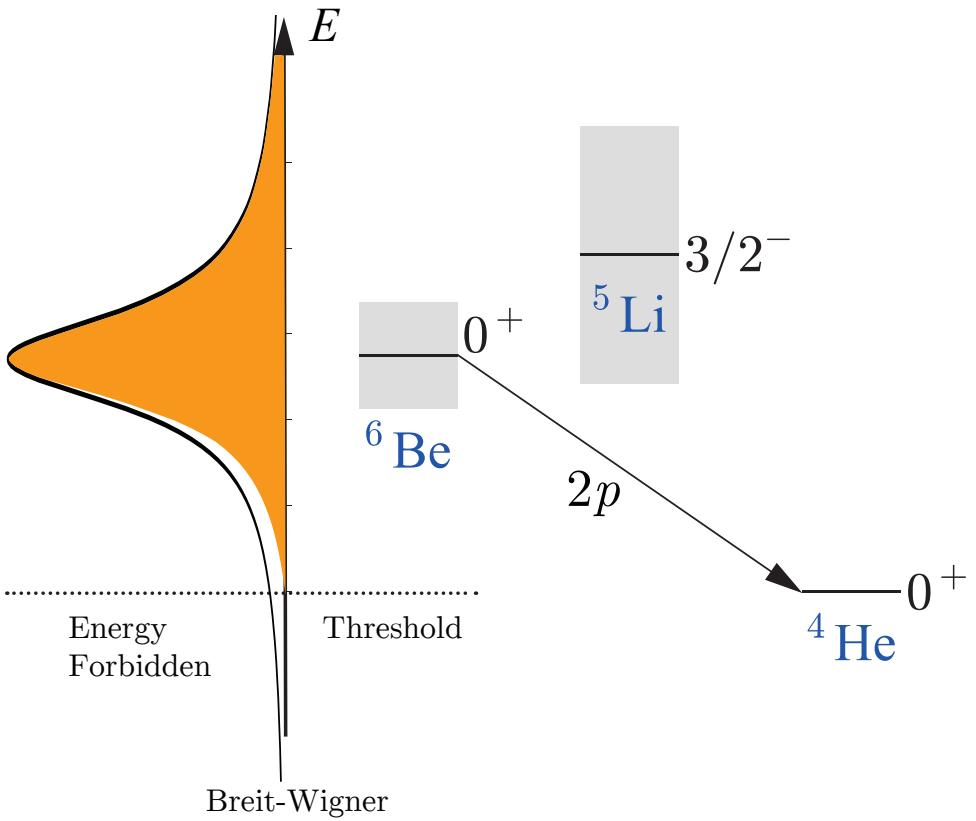
Density



Z. C. Xu, H. Y. Shang, SW, and Y. G. Ma, Phys. Rev. C (Letter) accepted

Energy dependence of the correlation in ^{6}Be

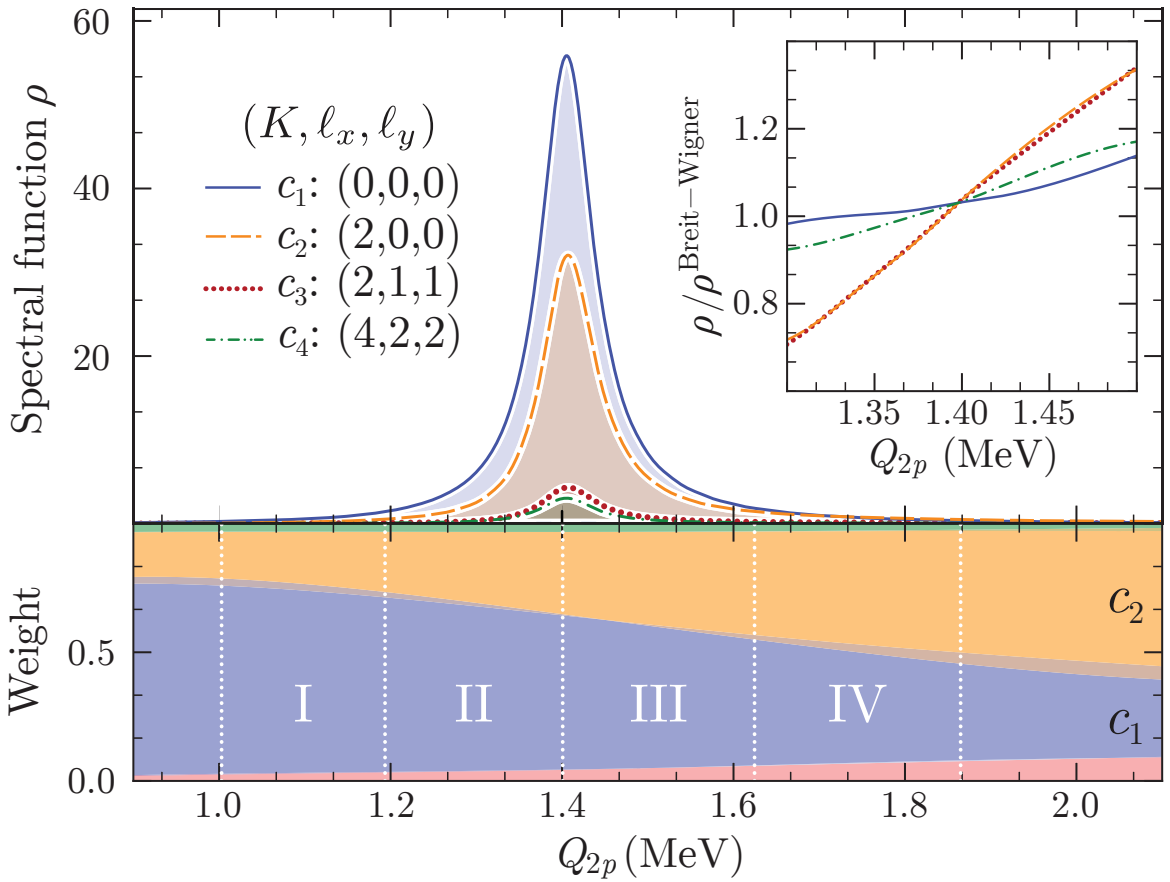


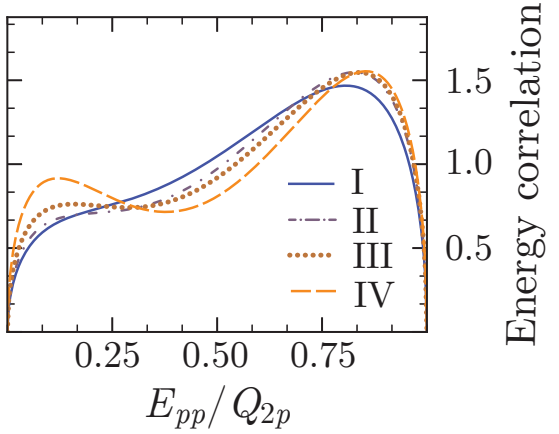


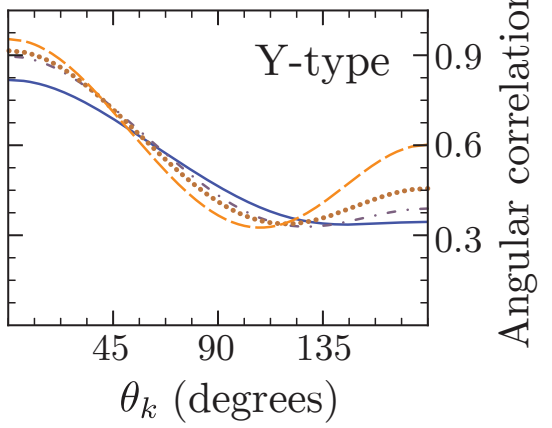
I. A. Egorova *et al.*, Phys. Rev. Lett. 109, 202502 (2012)

- Deviates from Breit-Wigner due to the threshold proximity.
- The threshold effect is channel-dependent.

Energy dependence of the correlation in ^{6}Be







- The weights of different components change as energy increases.
- Result in a energy-dependent correlation.

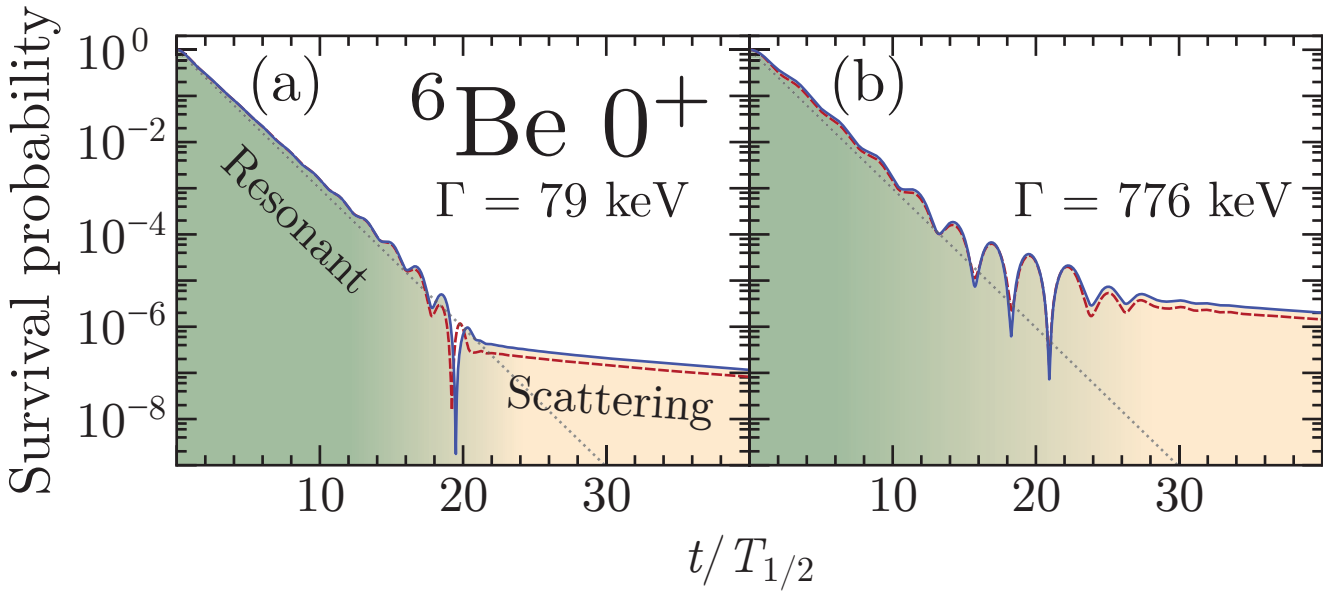
SW, W. Nazarewicz, A. Volya, and Y.G. Ma, Phys. Rev. Res. 5, 023183 (2023)

Non-exponential decay

Survival probability

$$\mathcal{S}(t) = |\langle\Psi(0)|\Psi(t)\rangle|^2 = \left|\int_0^{+\infty} \underline{\rho(E)} e^{-i\frac{E}{\hbar}t} \mathrm{d}E\right|^2$$

Spectral function



Ψ

Complex-energy Gamow state

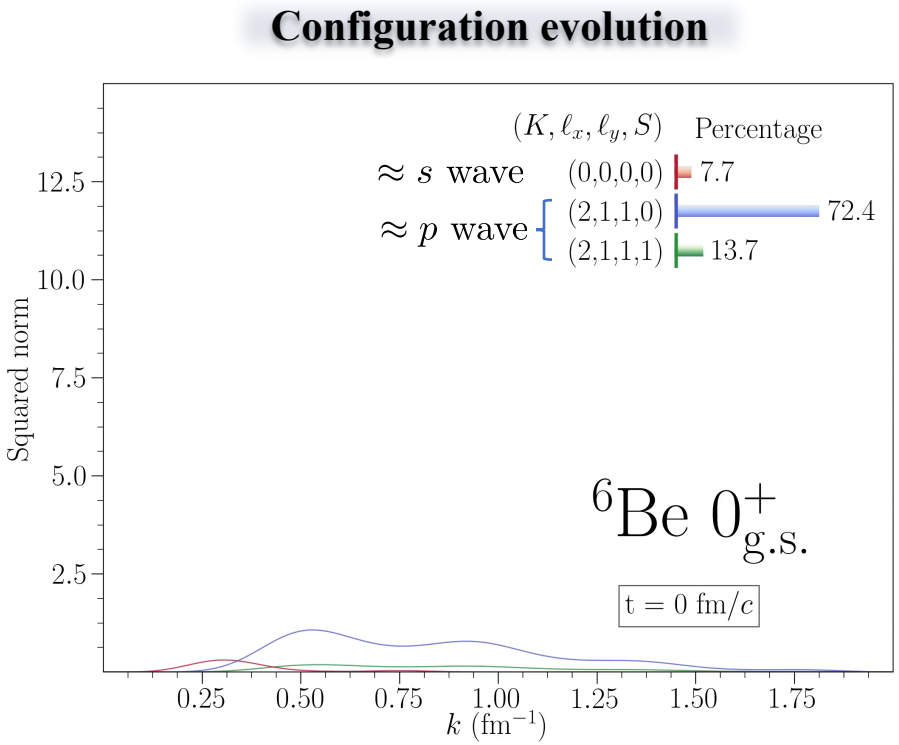
Ψ'

Expanded on harmonic oscillator basis

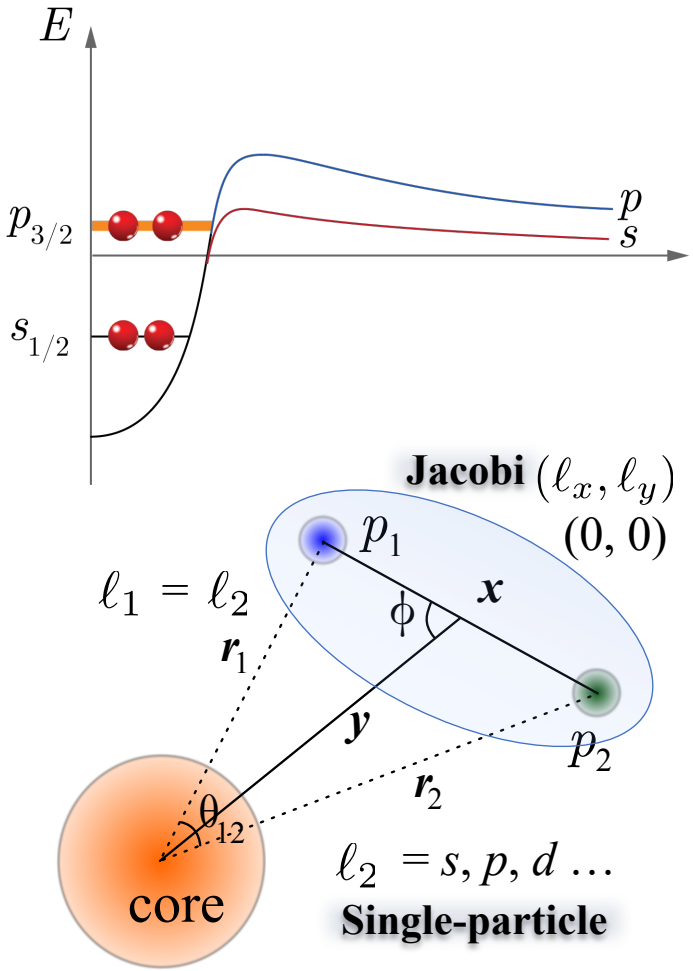
- The time evolution of a resonance contains exponential (resonant) and powered (scattering) decays.
- When the decay width is large enough, scattering feature is dominated.

SW, W. Nazarewicz, A. Volya, and Y.G. Ma, Phys. Rev. Res. 5, 023183 (2023)

Configuration evolution of ^{6}Be



Kinetic energy: $T = \dfrac{\hbar^2}{2m}k^2$

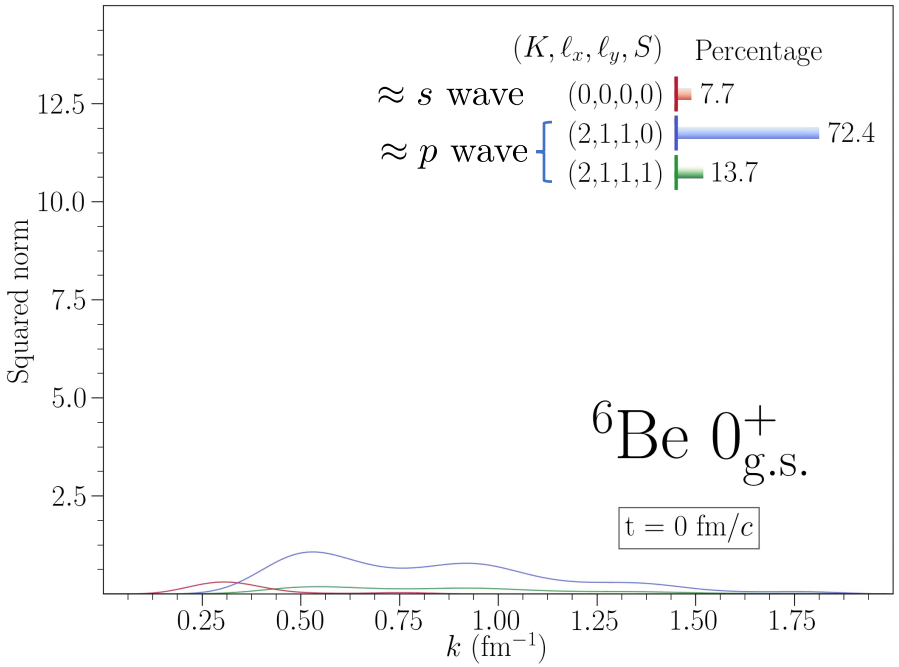


- p wave gradually transfers to s wave.
- The formation of diproton benefits tunneling process.

SW and W. Nazarewicz, Phys. Rev. Lett. 126, 142501 (2021)

Configuration evolution of ^{6}Be

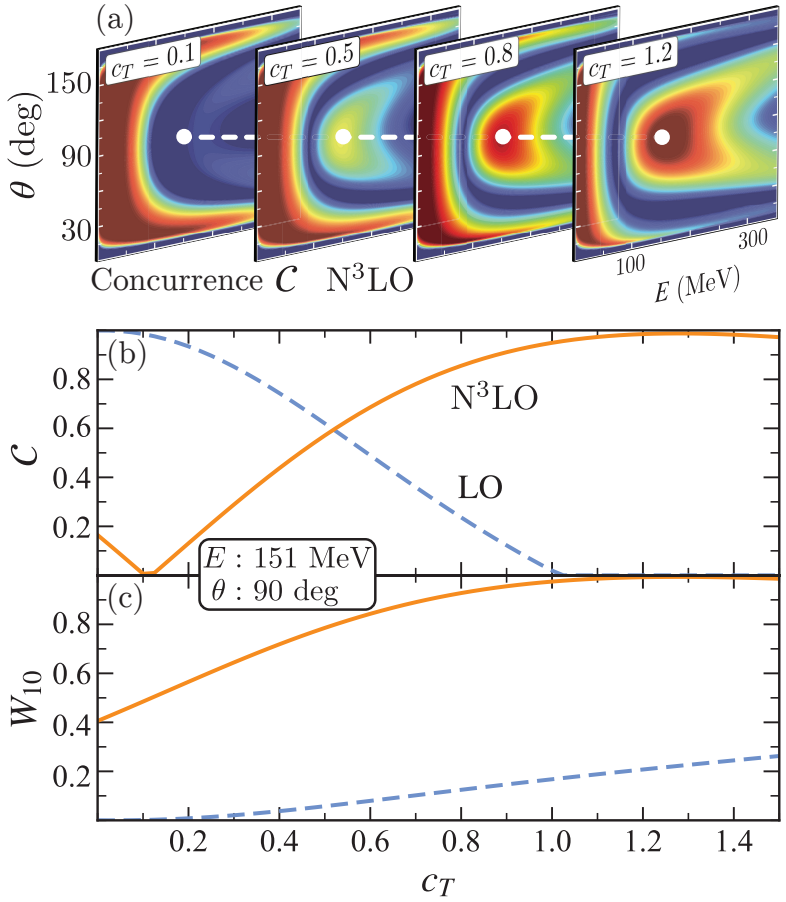
Configuration evolution



Kinetic energy: $T = \dfrac{\hbar^2}{2m}k^2$

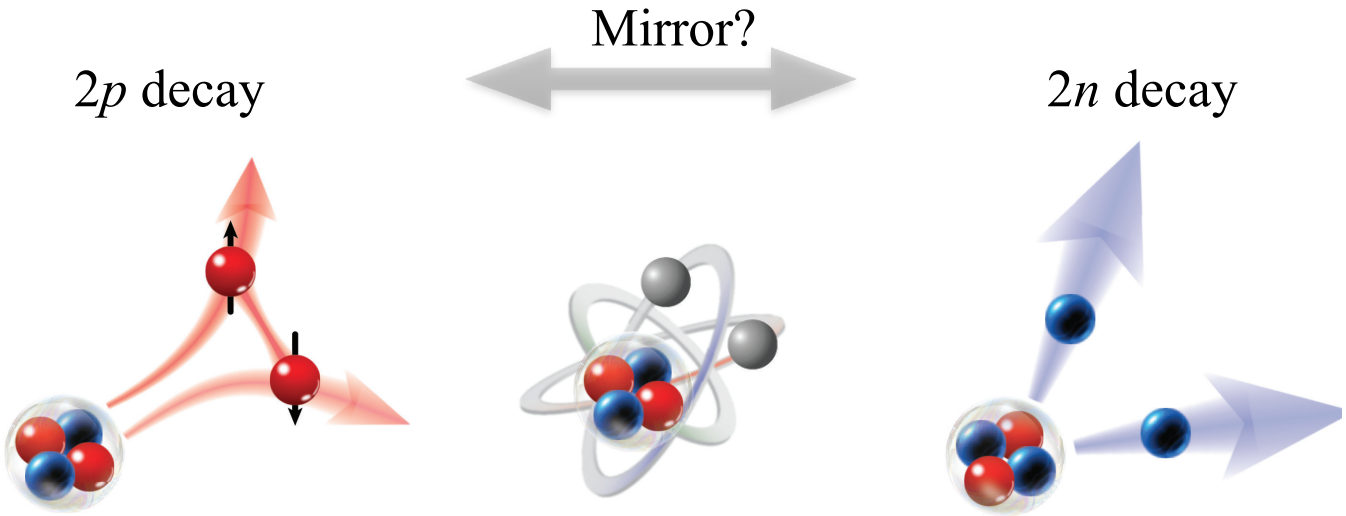
- p wave gradually transfers to s wave.
- The formation of diproton benefits tunneling process.

Probe nuclear force



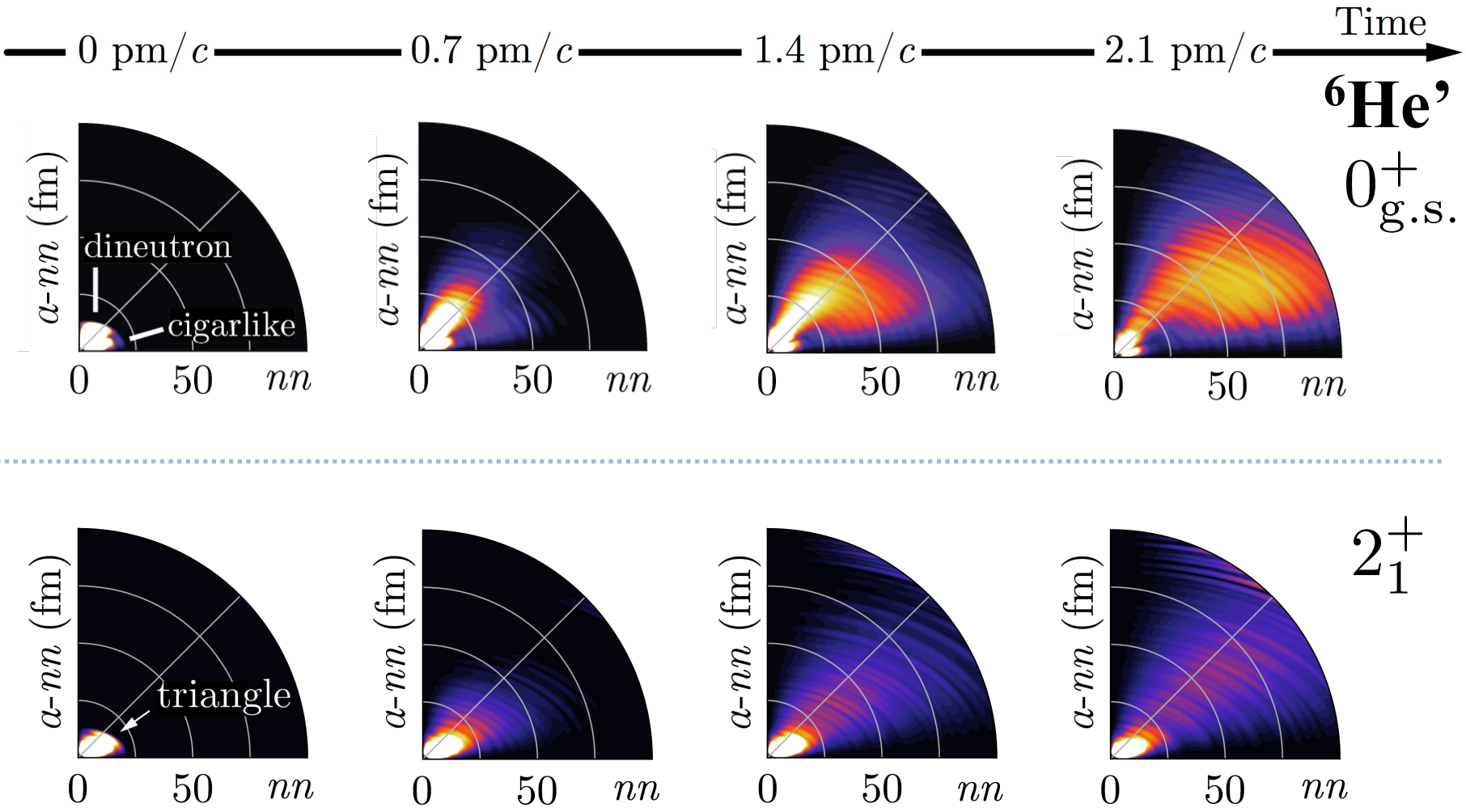
S. Z. Xin *et al.*, Arxiv 2510.24325 (2025)

2*p*/2*n* decay

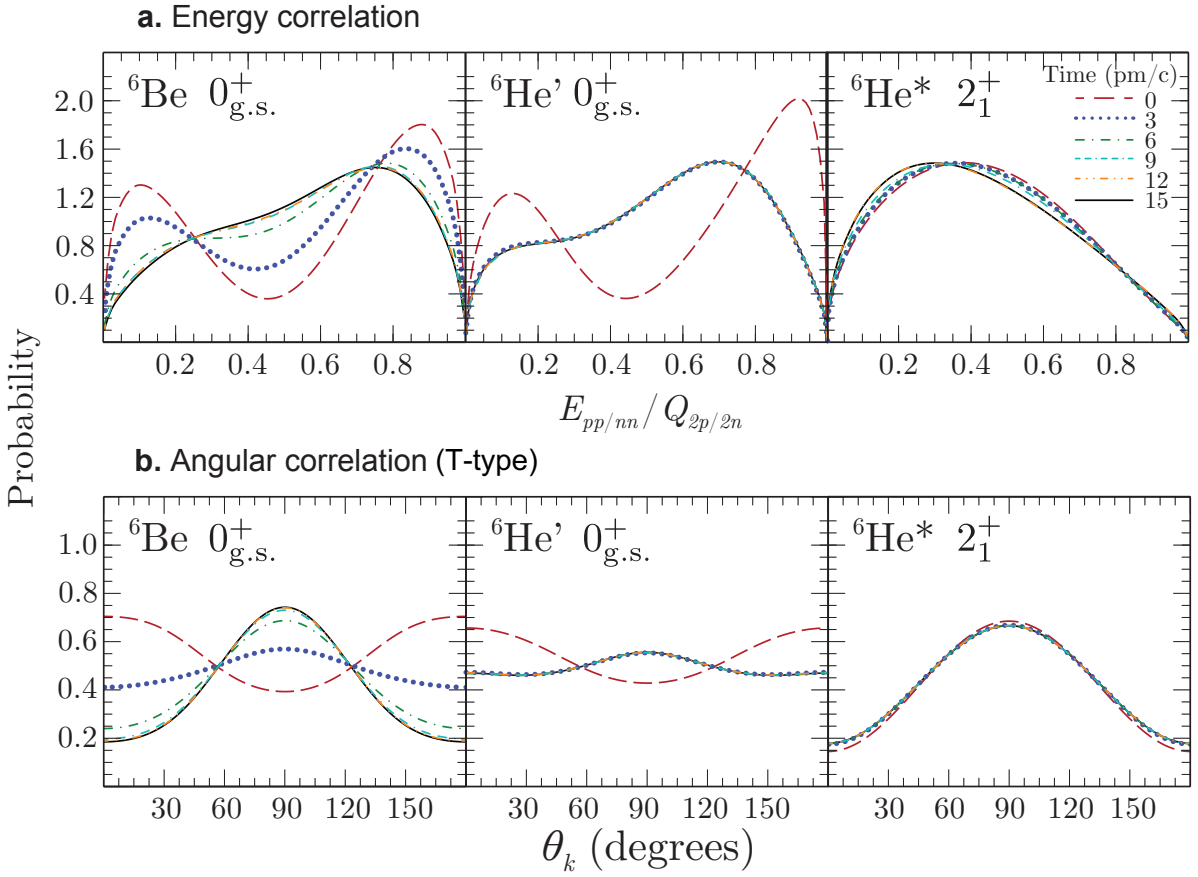


- The symmetry and asymmetry between 2*p* and 2*n* decays.
- Candidates: ^{16}Be, ^{26}O, ^{14}Be* …

Time evolution of ^{6}He'



Evolution of 2*p*/2*n* correlations

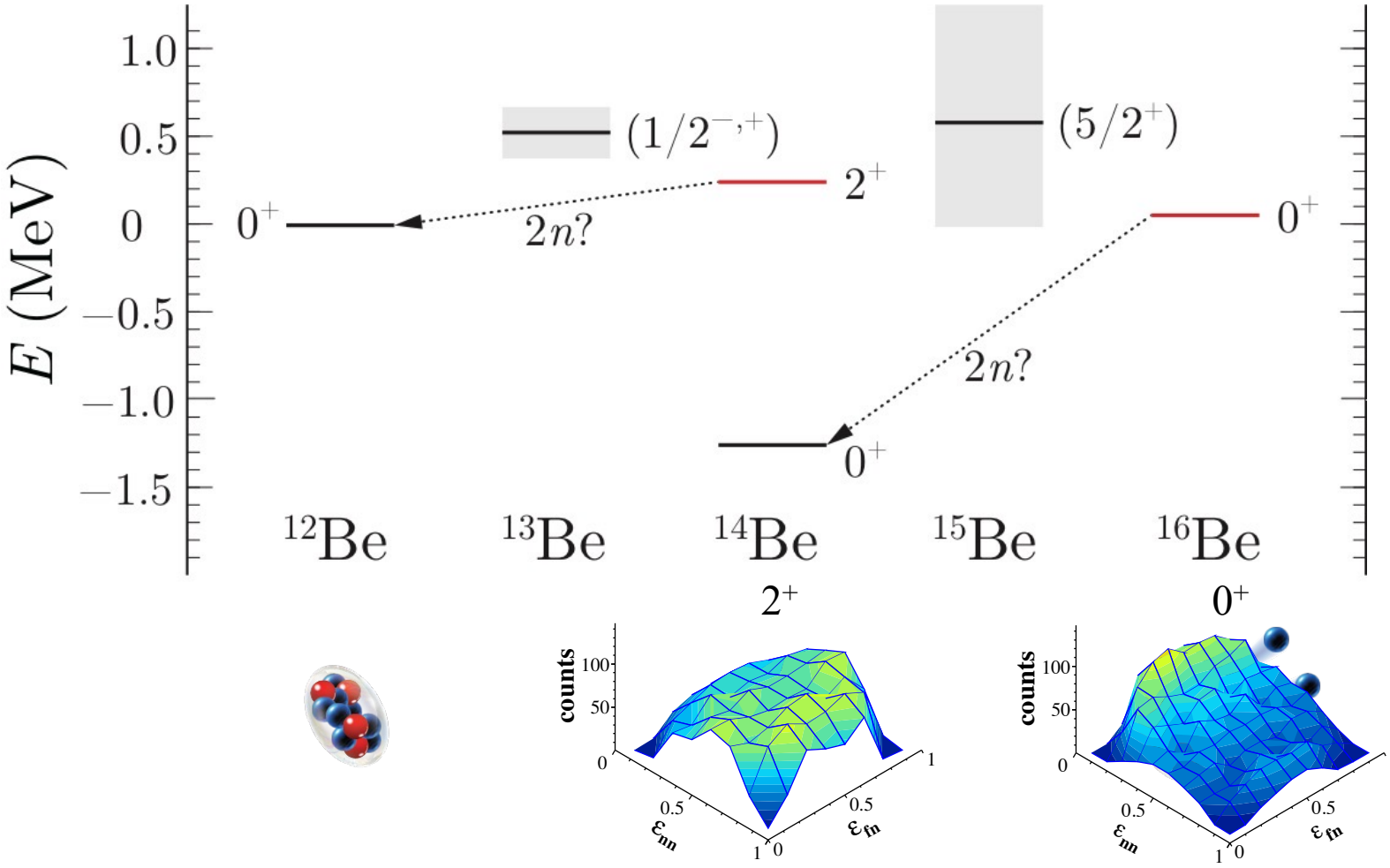


- ***pp***: subthreshold resonance L.P. Kok, PRL 45, 427 (1980)

  $k = 0.0647–i0.0870$ fm^{-1}; $E = –140$ keV; $\Gamma = 934$ keV

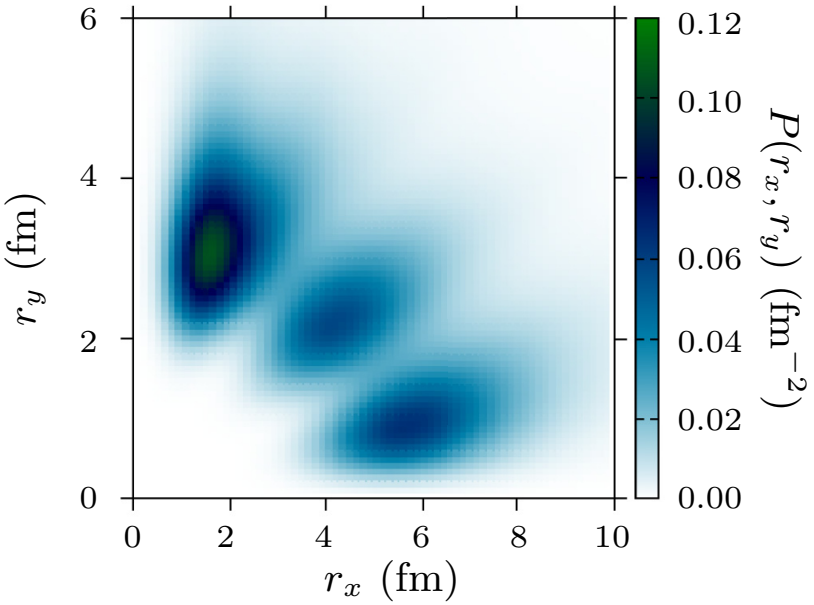
- ***nn***: antibound state, $k = –i0.0559(33)$ fm^{-1} V.A. Babenko, PAN 76, 684 (2013)

2*n* decay of ^{14,16}Be



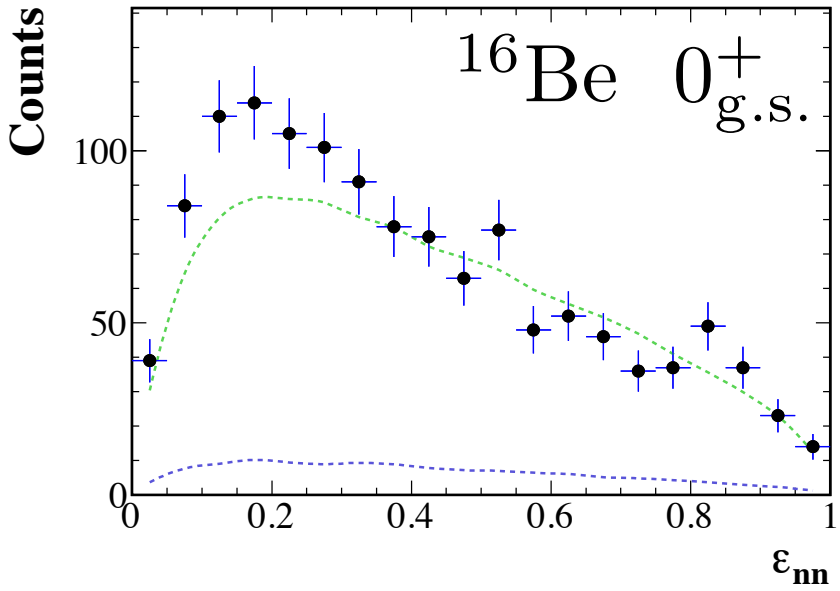
Structure and and correlation of ^{16}Be

Density distribution of ^{16}Be

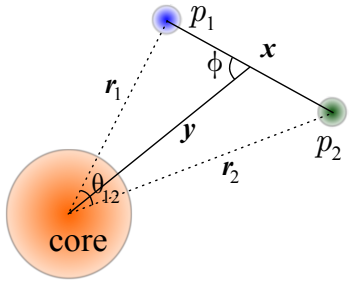


J. Casal *et al.*, Phys. Rev. C 99, 014604 (2019)
A. E. Lovell *et al.*, Phys. Rev. C 95, 034605 (2017)

***nn* energy correlation**



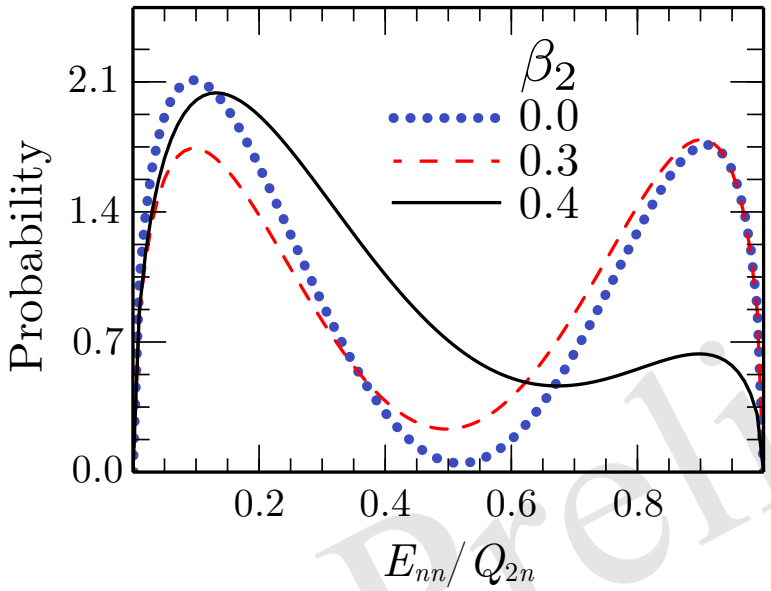
B. Monteagudo, J. Casal *et al.*, Phys. Rev. Lett. 132, 082501(2024)



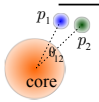
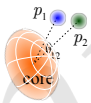
- The inner structure of ^{16}Be is dominated by *d*-wave component.
- Asymptotic correlation indicates *s*-wave component.
- *pp* & *nn* correlations of *sd*-shell nuclei.

Impact of deformation

nn energy correlation of ^{16}Be



Decay widths and configurations of ^{16}Be

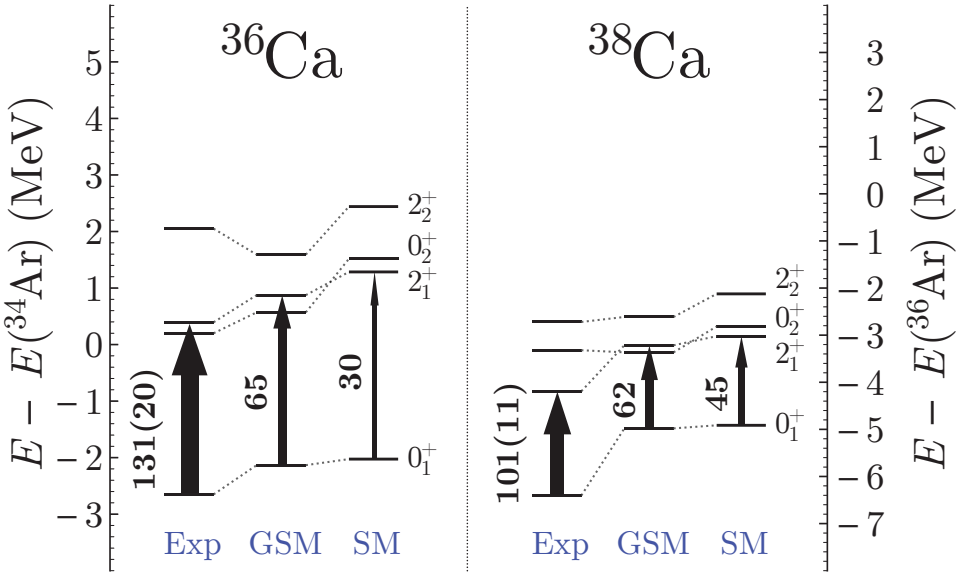
	β_2	E (MeV)	Γ (keV)	Configuration
	0.0	1.486	24	90.1% $(d_{5/2})^2$
				2.6% $(p_{3/2})^2$
				2.1% $(p_{1/2})^2$
				0.2% $(s_{1/2})^2$
	0.4	1.286	547	3.4% $(d_{5/2})^2$
				5.8% $(p_{3/2})^2$
				2.1% $(p_{1/2})^2$
				72.8% $(s_{1/2})^2$

Preliminary

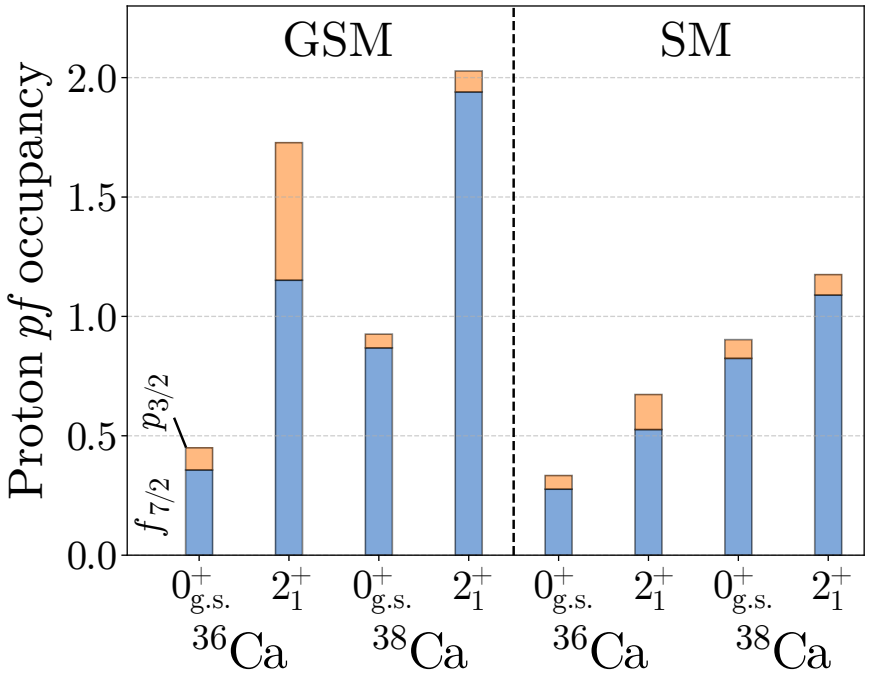
- In spherical case, $s_{1/2}$ orbital is occupied by the core due to the halo structure.
- Deformation causes the mixing among different orbitals.
- $s_{1/2}$ component dramatically changes the decay width and energy correlations.

Contiuum effect on spectroscopic factor

Spectra and $B(E2)$ values of ^{36,38}Ca



Cross-shell excitations



- Continuum enhances the cross-shell effect.
- p wave is strongly impacted by the continuum.

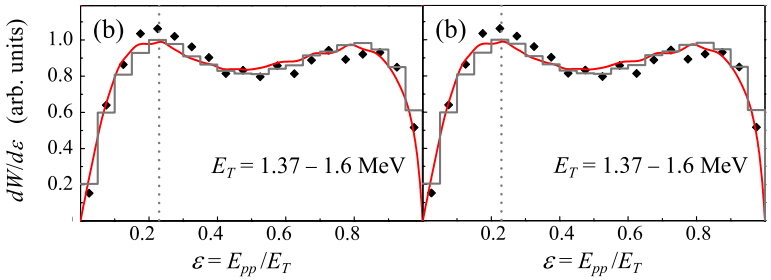
Z. Xu, SW *et al.*, Phys. Rev. C 112, L011302 (2025)
J. Wylie *et al.*, Phys. Rev. C 104, L061301
M. R. Xie *et al.*, Phys. Rev. C 110, 054301 (2024)

Exotic phenomena of 2*p* decay



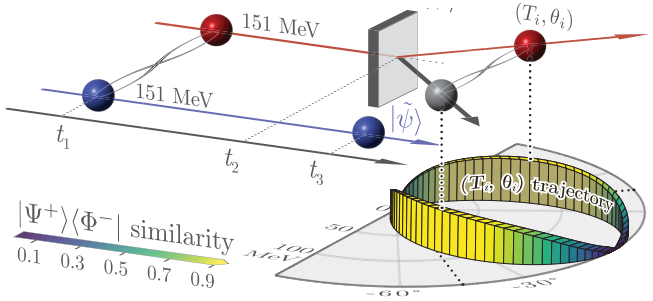
2*p* decay

I. A. Egorova *et al.*, PRL 109, 202502 (2012)



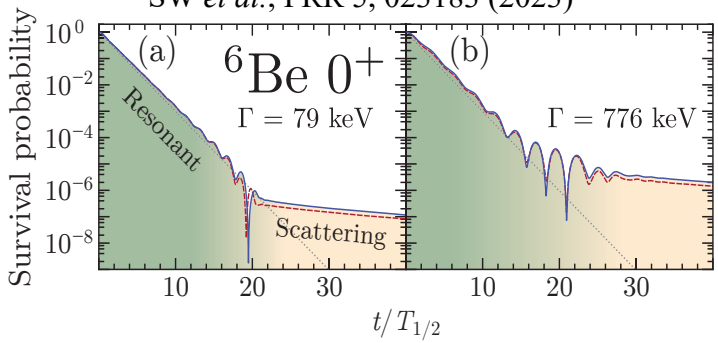
***E*-dependent *nn* correlation**

Z. X. Shen *et al.*, Arxiv 2510.24325



Entanglement

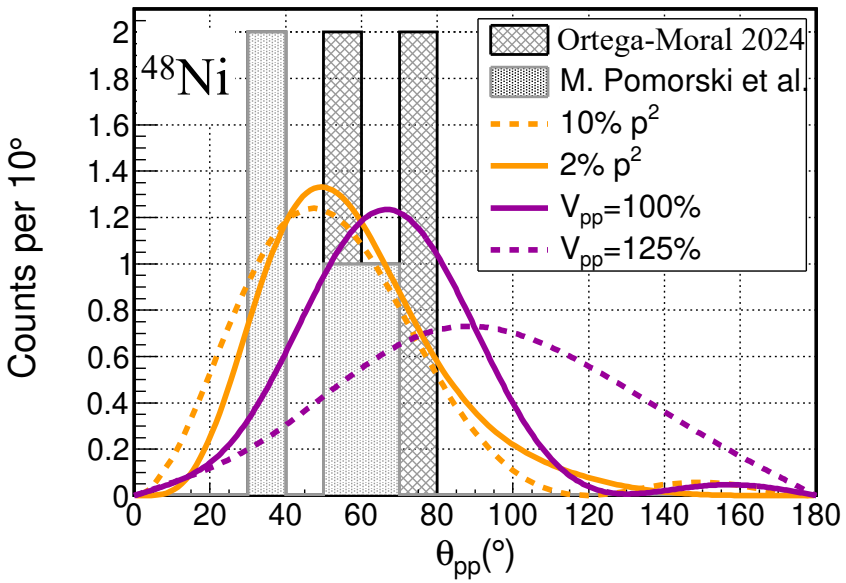
SW *et al.*, PRR 5, 023183 (2023)



Non-exp decay

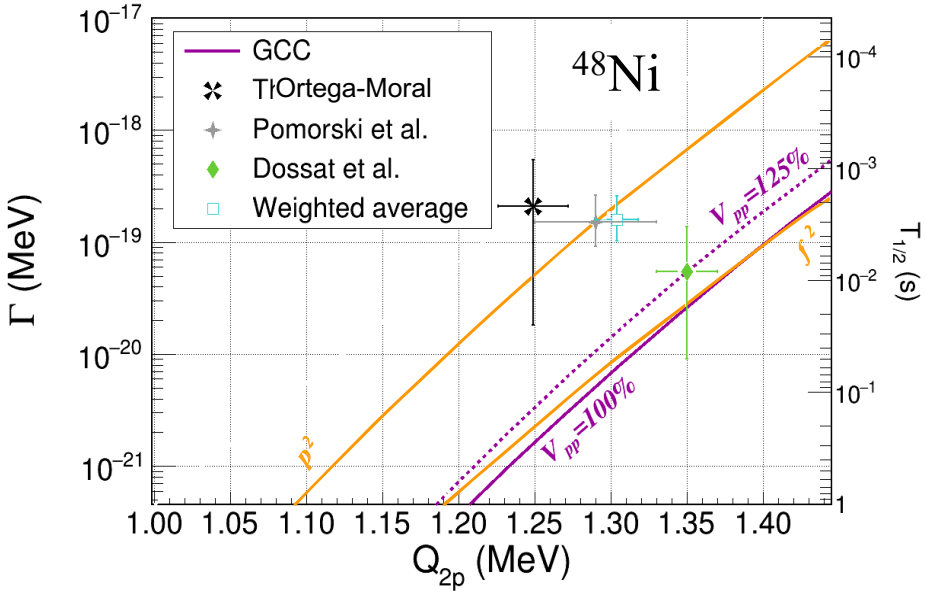
Asymptotic correlation of ^{45}Fe and ^{48}Ni

Angular correlation of ^{48}Ni



$f^2_{7/2}$	$p^2_{3/2}$	$p^2_{1/2}$	$f^2_{5/2}$	$s^2_{1/2}$
91.6%	4.7%	1.0%	1.0%	0.1%

Half-live of ^{48}Ni

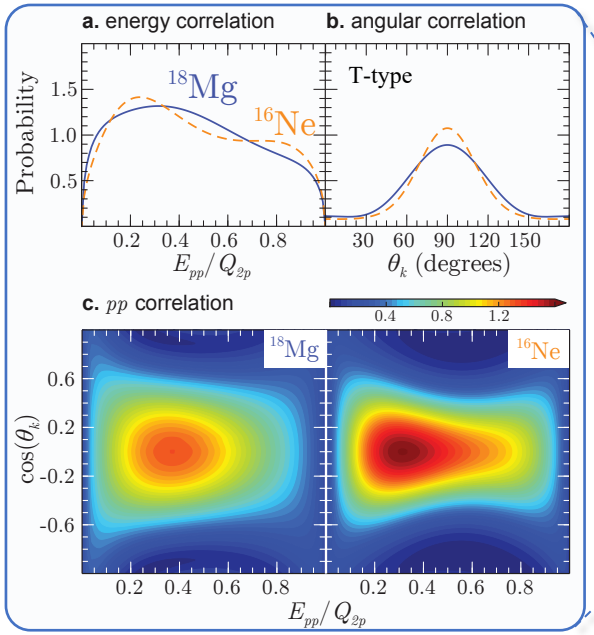


Q^{Exp}_{2p} (keV)		Q^{Cal}_{2p} (keV)		
Ortega-Moral	Pomorski	Brown	Ormand	Cole
1249(23)	1290(40)	1360(130)	1290(330)	1350(60)

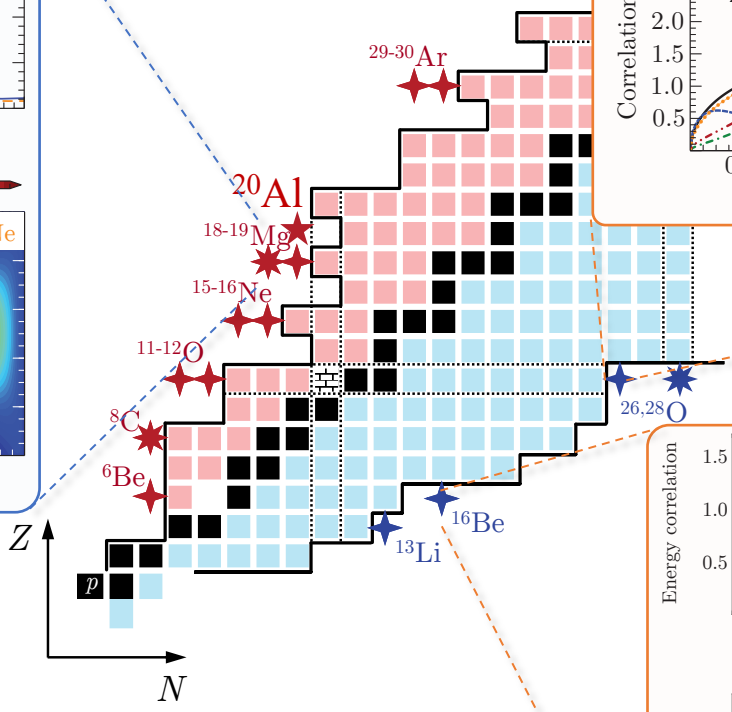
- Closed shell behavior for ^{48}Ni?
- Discrepancy between correlations and half-lives.

A. O. Moral, SW *et al.*, Phys. Rev. C 112, L061302 (2025)

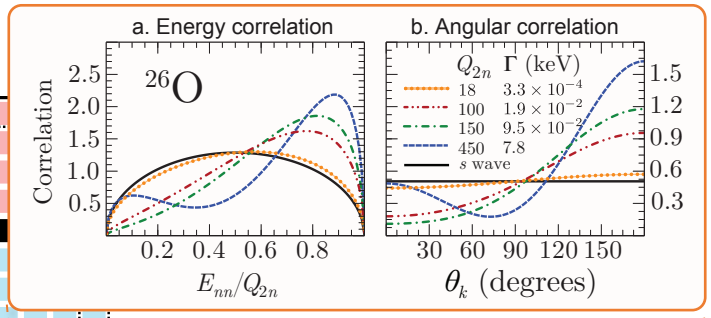
Correlations in light-mass nuclei



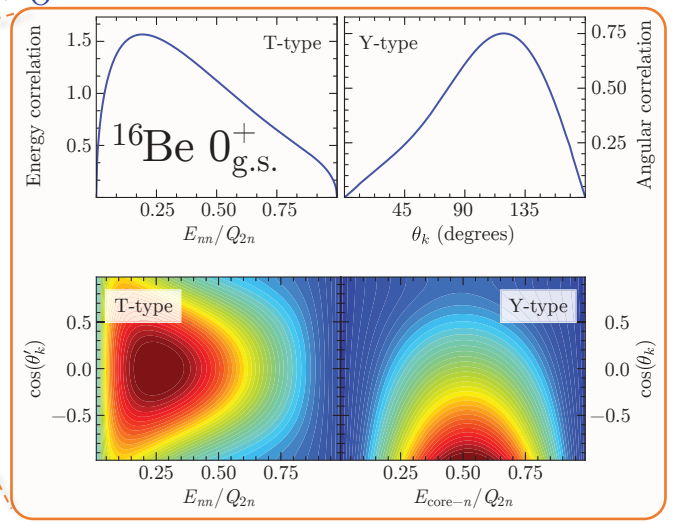
L. Zhou, SW *et al.*,
Nucl. Sci. Tech. 35, 107 (2024)



SW *et al.*, J. Phys. G 49, 10LT02 (2022)



Y. R. Lin in preparation



B. Monteagudo *et al.*, Phys. Rev. Lett. 132, 082501(2024)

- $4p$ ($2p$+$2p$) decay of ^{18}Mg.
- Multi-proton emissions.
- Correlation changes when $Q \rightarrow 0$.

2*n*/4*n* decay candidate ^{26}O/ ^{28}O

^{26}O:

$Q_{2n} = 150^{+50}_{-150}$ keV — E. Lunderberg *et al.*, PRL 108, 142503 (2012)

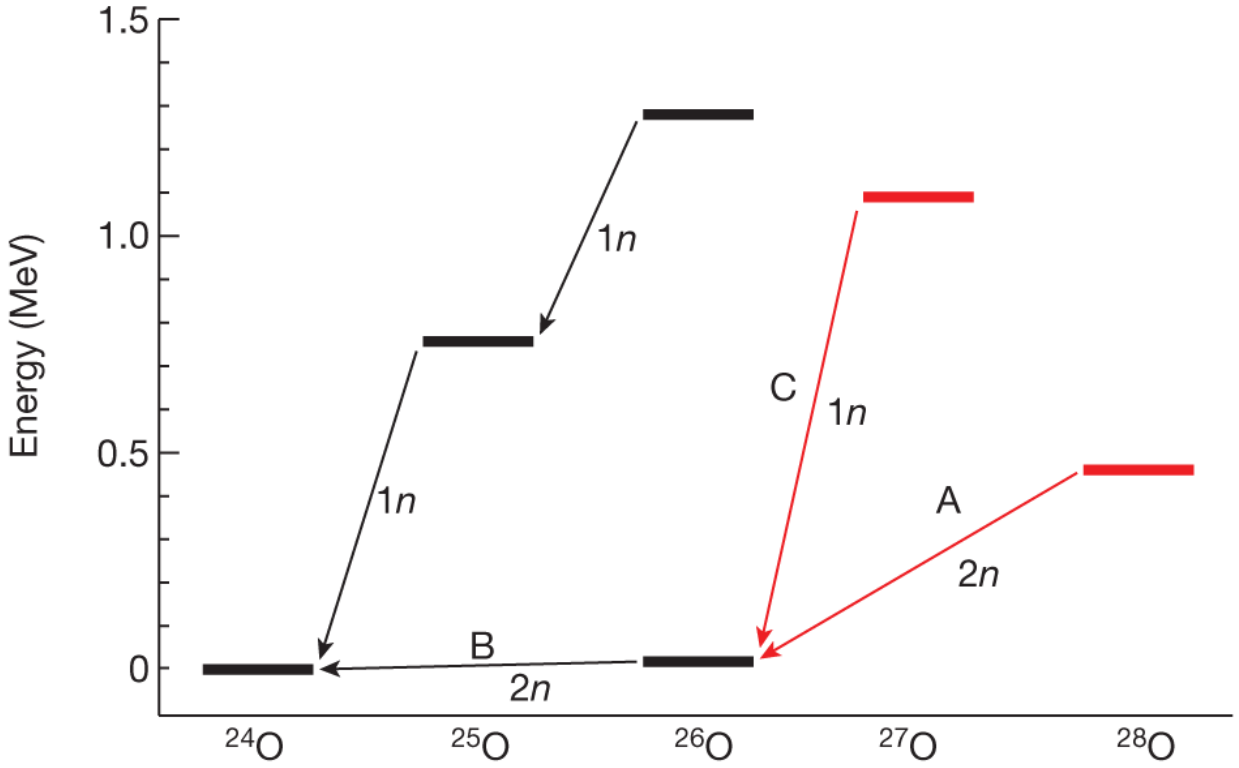
< 53 keV — Z. Kohley *et al.*, PRL 91, 034323 (2015)

$= 18 \pm 7$ keV — Y. Kondo *et al.*, PRL 116, 102503 (2016)

^{28}O:

$Q_{4n} = 0.46^{+0.05}_{-0.04}(\text{stat}) \pm 0,02(\text{syst})$ MeV

Y. Kondo *et al.*, Nature 620, 965 (2023)



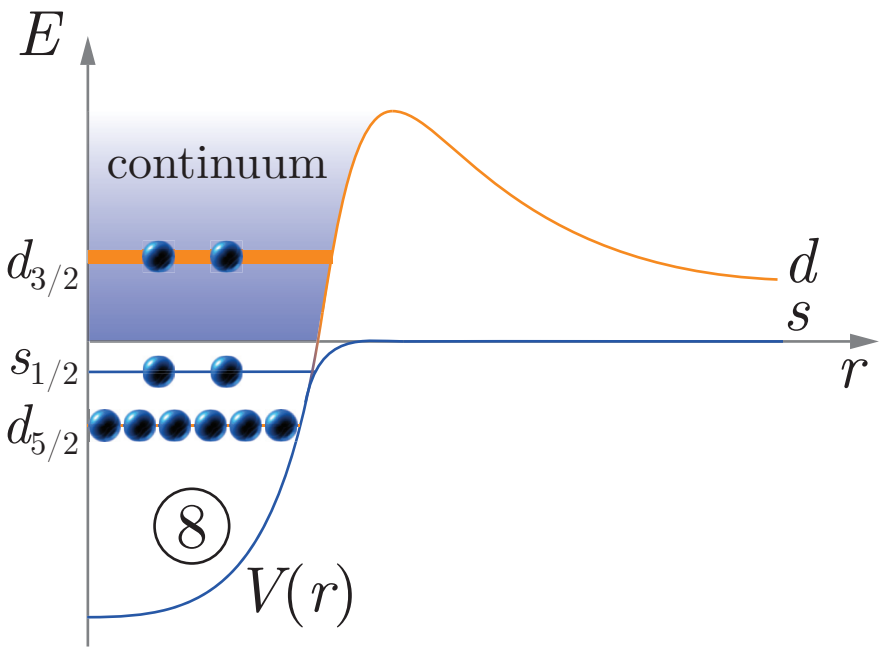
Inner structure of ^{26,28}O

- Threshold resonance:

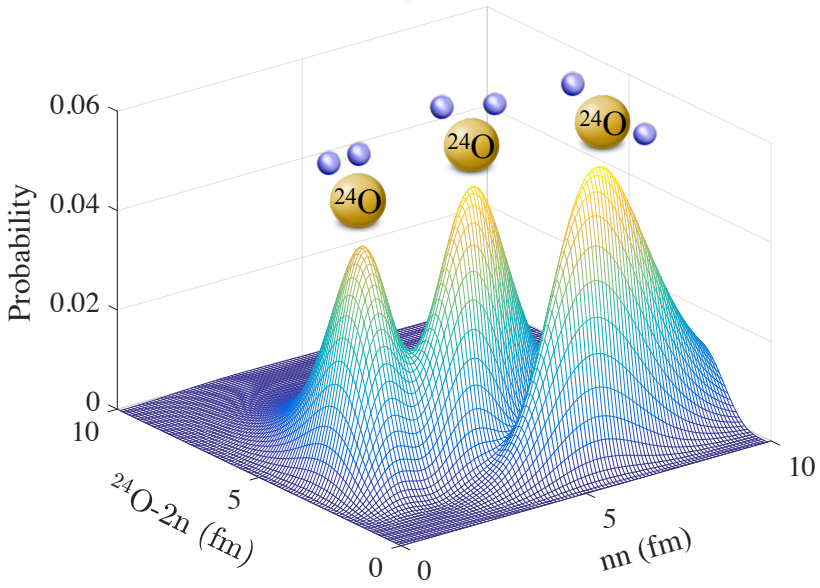
$Q_{2n} = 150^{+50}_{-150}$ keV — E. Lunderberg *et al.*, PRL 108, 142503 (2012)

< 53 keV — Z. Kohley *et al.*, PRL 91, 034323 (2015)

$= 18 \pm 7$ keV — Y. Kondo *et al.*, PRL 116, 102503 (2016)



Calculated density distribution of ^{26}O



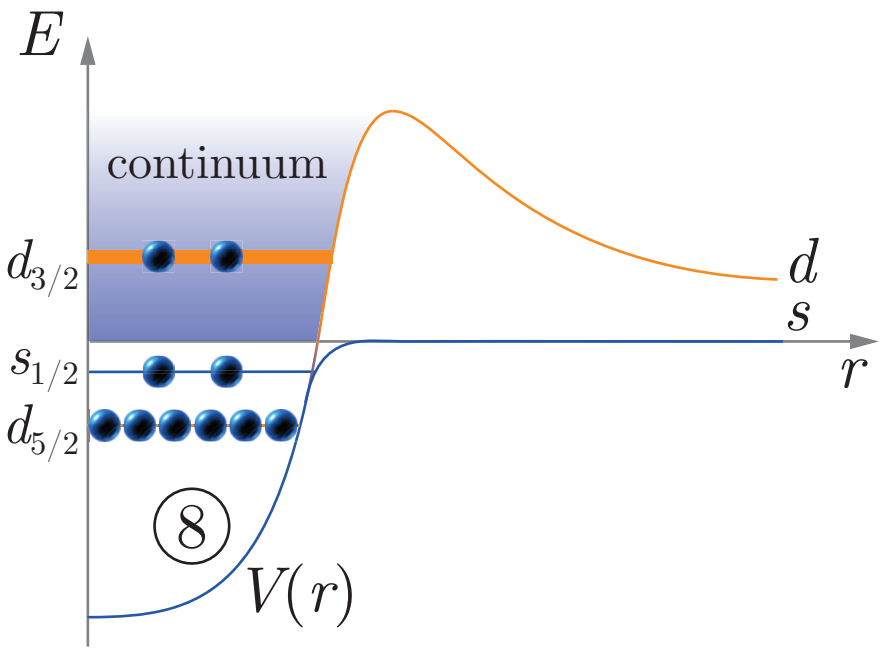
Decay dynamics of ^{26}O

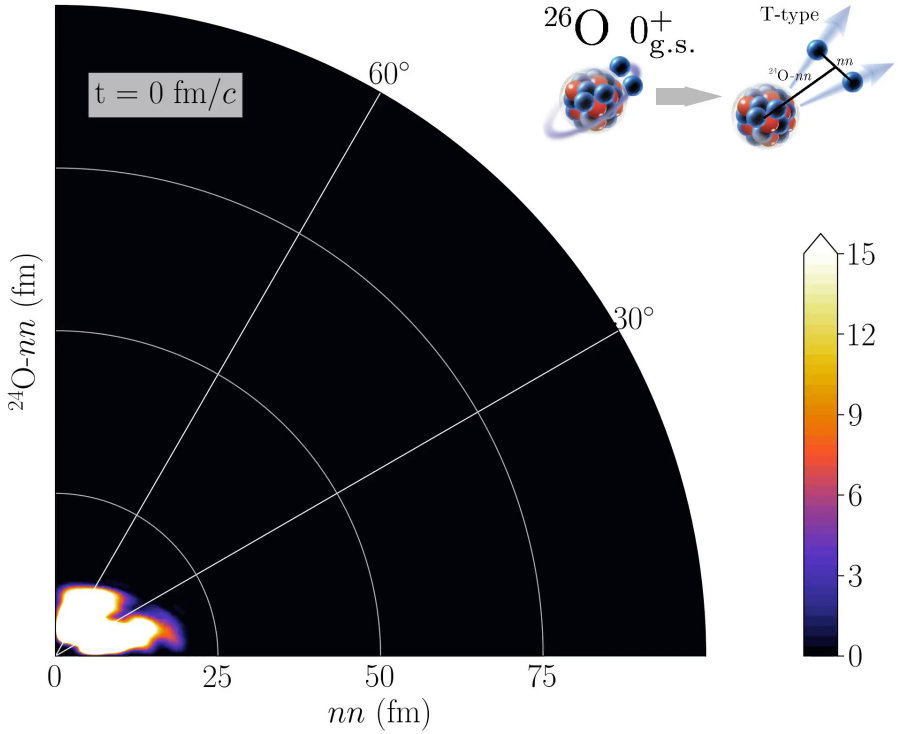
- Threshold resonance:

$Q_{2n} = 150^{+50}_{-150}$ keV — E. Lunderberg *et al.*, PRL 108, 142503 (2012)

< 53 keV — Z. Kohley *et al.*, PRL 91, 034323 (2015)

$= 18 \pm 7$ keV — Y. Kondo *et al.*, PRL 116, 102503 (2016)





Asymptotic correlations of ^{26}O

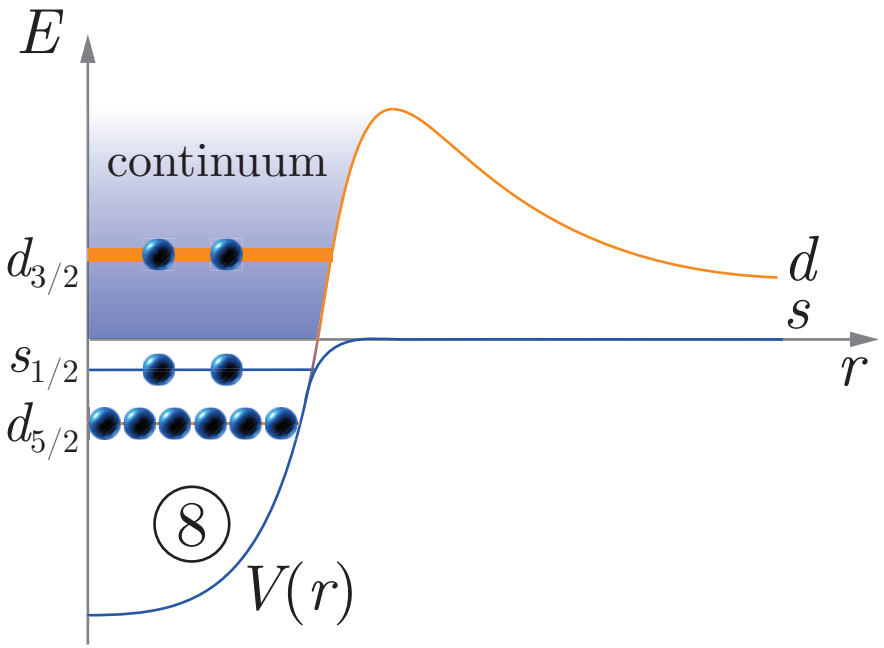
- Threshold resonance:

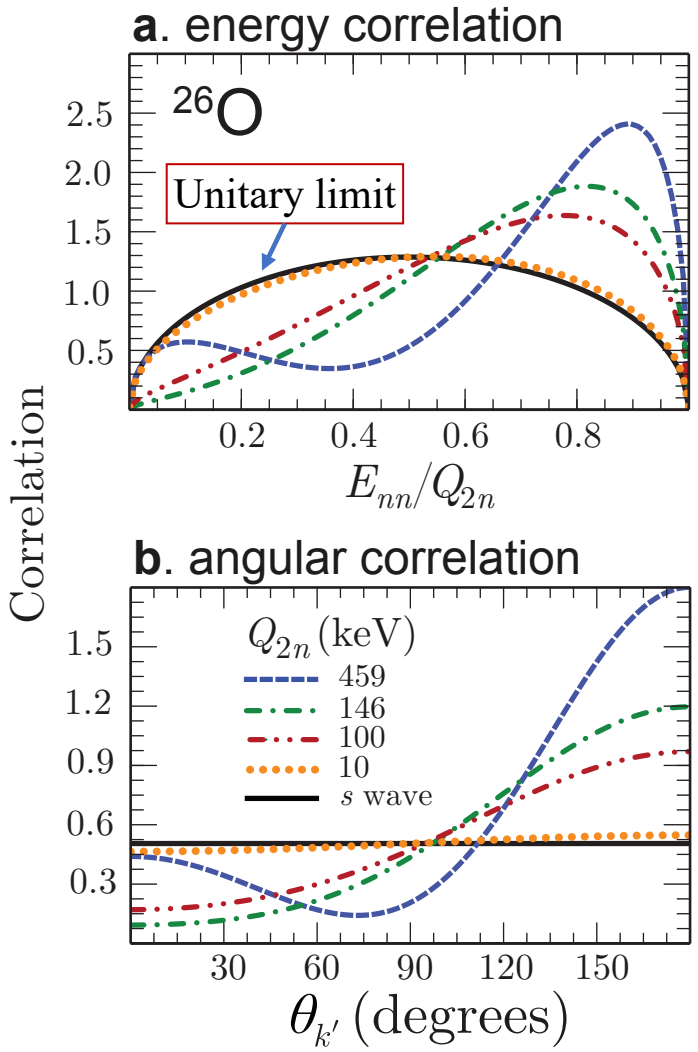
$Q_{2n} = 150^{+50}_{-150}$ keV — E. Lunderberg *et al.*, PRL 108, 142503 (2012)

< 53 keV — Z. Kohley *et al.*, PRL 91, 034323 (2015)

$= 18 \pm 7$ keV — Y. Kondo *et al.*, PRL 116, 102503 (2016)

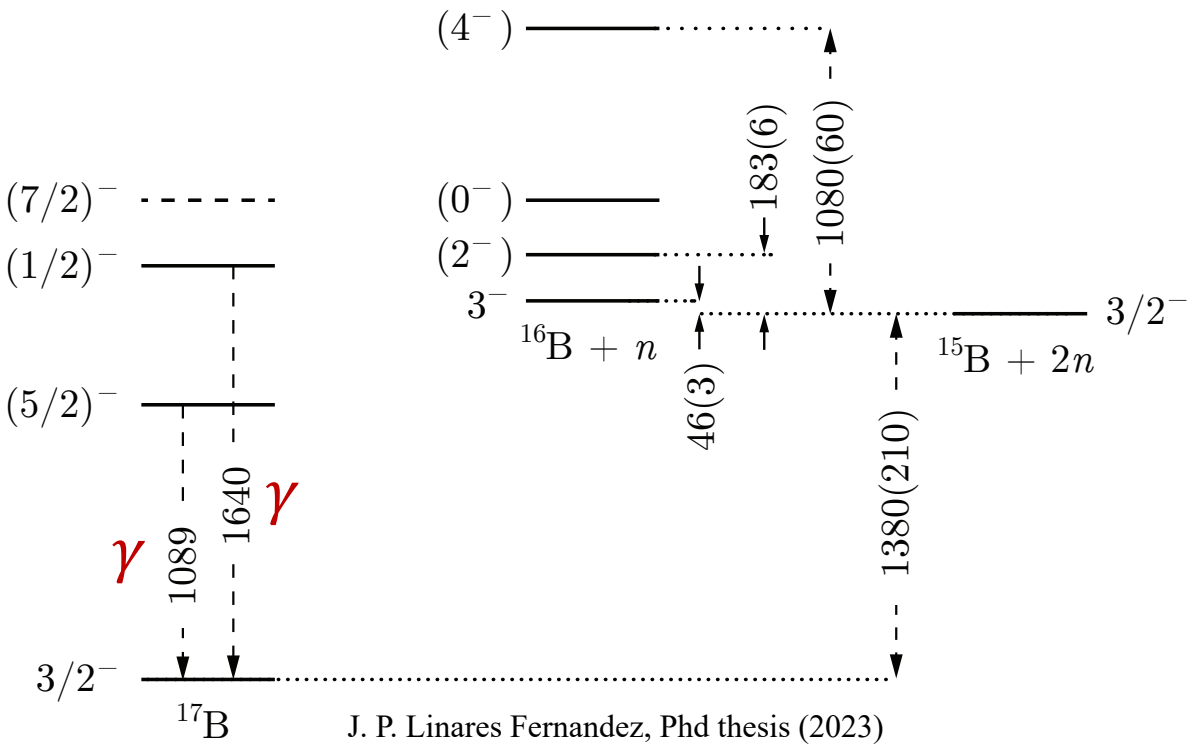
- *nn* correlations can be very different between ^{26}O and ^{28}O





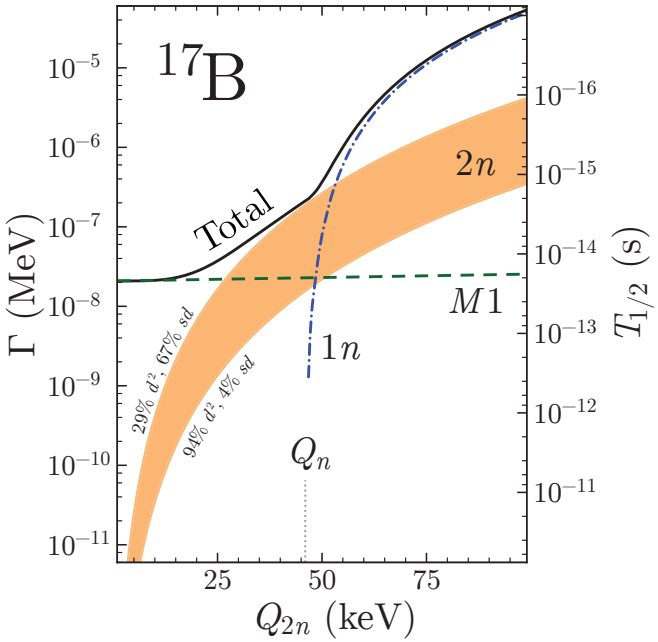
Exotic threshold resonance in ^{17}B

Spectra of ^{15,16,17}B



J. P. Linares Fernandez, Phd thesis (2023)
Z. H. Yang *et al.*, Phys. Rev. Lett. 126, 082501 (2021)

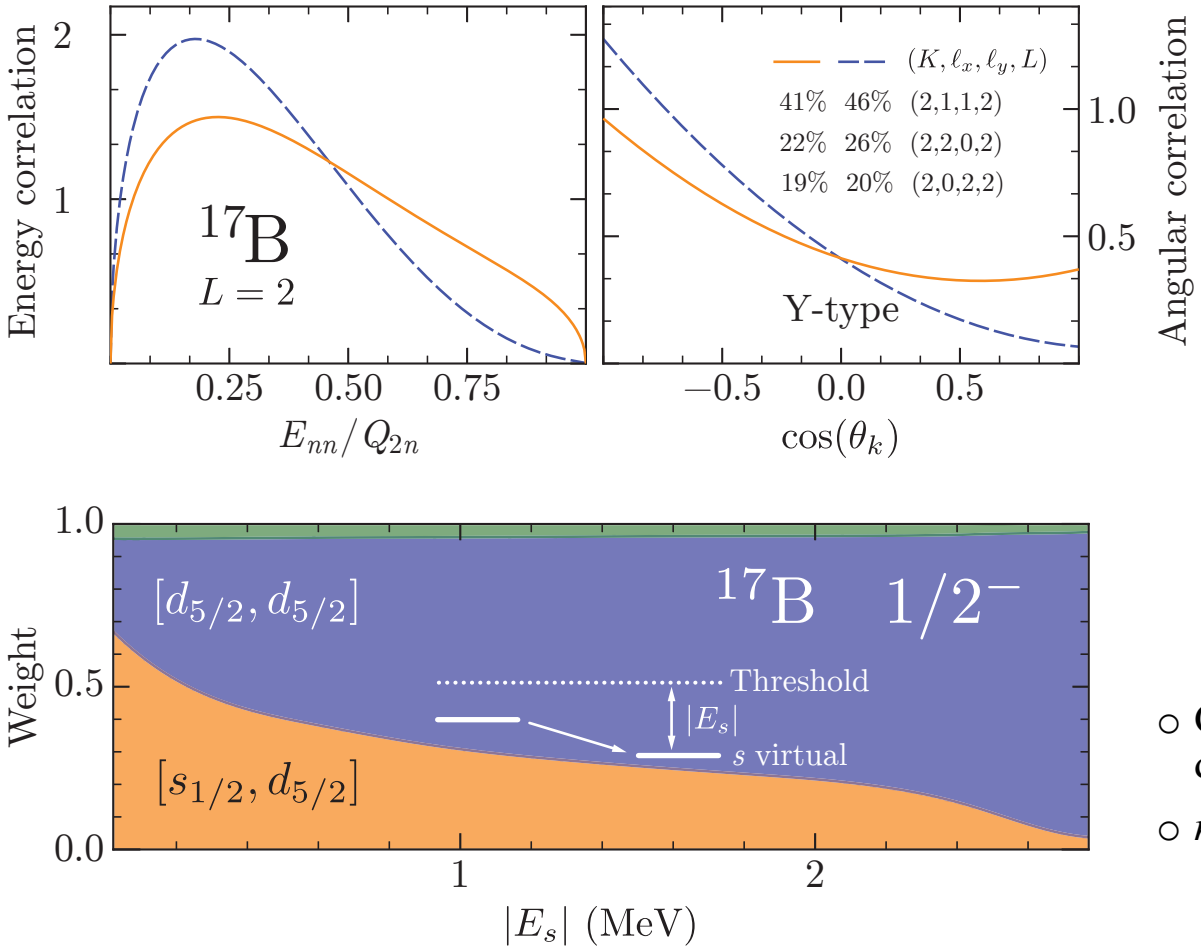
Partial decay widths

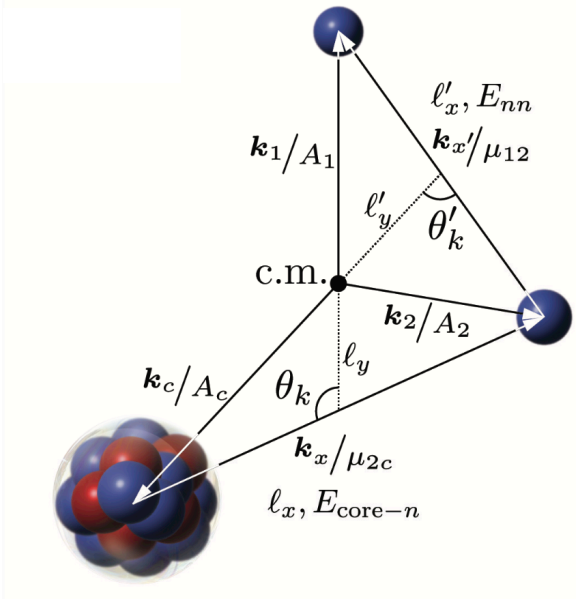


A. Volya, SW *et al.*, Phys. Rev. Res. 8, 013125 (2026)

- The excited states of ^{17}B have been observed, along with the γ decays.
- Through the branching analysis, this newly observed state is extremely close to the threshold.

$L = 2$ $2n$ decay



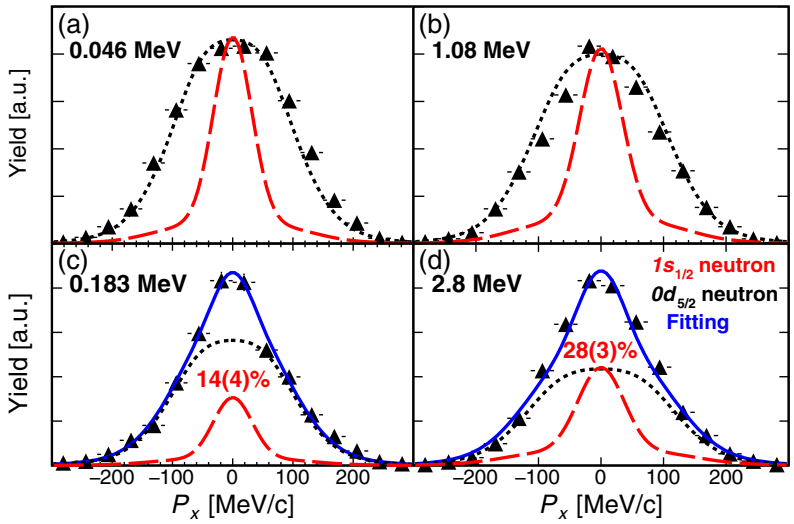


- Compared with $L = 0$ $2n$ decay, ^{17}B $2n$ decay has a different patten.
- *nn* correlation is sensitive to structure.

A. Volya, SW *et al.*, Phys. Rev. Res. Accepted (2025)

Spectroscopic factors of ^{17}B

Transverse momentum distributions for ^{16}B



Z. H. Yang *et al.*, Phys. Rev. Lett. 126, 082501 (2021)

- ^{17}B has large *s*-wave component.
- Knockout might not result in *s*-wave neutrons due the spectroscopic factor.

Spectroscopic factor

Block	ℓ	^{16}B intermediate state J^π 0^-	3^-	2^-	1^-	4^-
E_x (MeV)		1.48	0.00	0.14	2.75	1.03 ← Continuum
		0.29	0.00	0.38	1.72	1.27
$^{17}\mathrm{B} \to {}^{16}\mathrm{B}$	s	0.34	—	—	0.21	—
		0.69			0.04	
	d	—	0.11	0.31	0.03	—
			0.33	0.47	0.00	
$^{16}\mathrm{B} \to {}^{15}\mathrm{B}_{\mathrm{g.s.}}$	s	—	—	0.00	0.18	—
				0.58	0.54	
	d	0.08	0.42	0.60	0.51	0.74
		0.08	0.53	0.40	0.27	0.74
$^{17}\mathrm{B}(p,pn)$	s	—	—	0.07	0.04	—
				0.15	0.04	
	d	0.01	0.86	0.60	0.12	0.68
		0.02	0.75	0.10	0.04	0.51
$^{17}\mathrm{C}(p,2p)$	p	0.22	0.76	0.28	0.37	—
		0.95	0.40	0.02	0.31	

Spectroscopic factor

A. Volya, SW *et al.*, Phys. Rev. Res. 8, 013125 (2026)