# Structure and Electroweak Transitions of Light Nuclei

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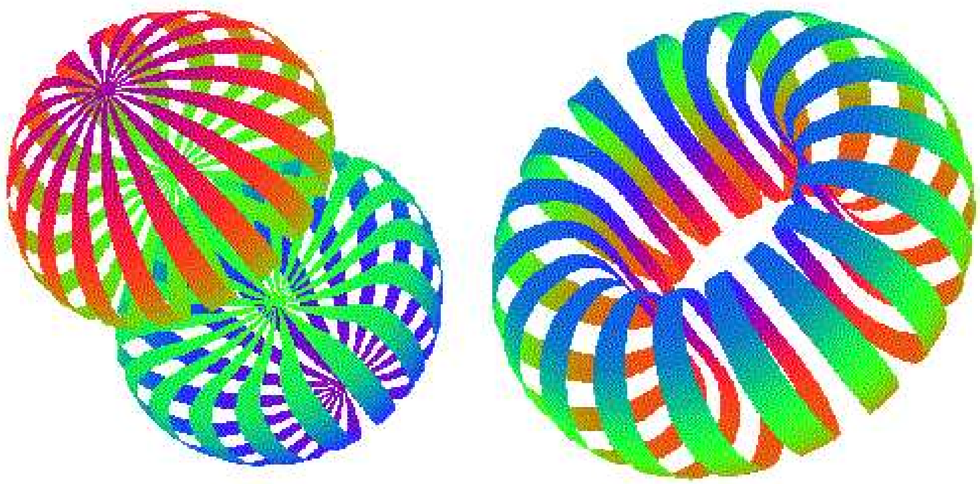

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# *Ab Initio* Calculations of Light Nuclei

## Goals

Understand nuclei at the level of elementary interactions between individual nucleons, including

- Binding energies, excitation spectra, relative stability, matter properties
- Densities, electromagnetic moments, transition amplitudes, spectroscopic overlaps
- Low-energy $NA$ & $AA'$ scattering, asymptotic normalizations, astrophysical reactions

## Requirements

- Two-nucleon potentials that accurately describe elastic $NN$ scattering data
- Consistent three-nucleon potentials and electroweak current operators
- Accurate methods for solving the many-nucleon Schrödinger equation

## Results

- Quantum Monte Carlo methods can evaluate realistic Hamiltonians accurate to ∼1–2%
- About 100 states calculated for $A \leq 12$ nuclei in good agreement with experiment
- Applications to elastic & ineleastic $e, \nu, \pi$ scattering, $(e, e'p)$, $(d, p)$ reactions, etc.
- Electromagnetic moments, $M1$, $E2$, F, GT transitions, electroweak response
- $^5$He = $n\alpha$ scattering and $3 \leq A \leq 9$ ANCs and widths

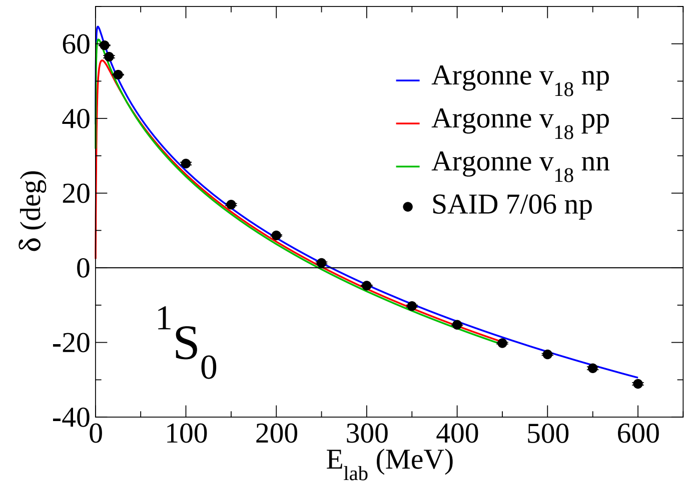
# NUCLEAR HAMILTONIAN


$$H = \sum_i K_i + \sum_{i<j} v_{ij} + \sum_{i<j<k} V_{ijk}$$

$K_i$: Non-relativistic kinetic energy, $m_n$-$m_p$ effects included

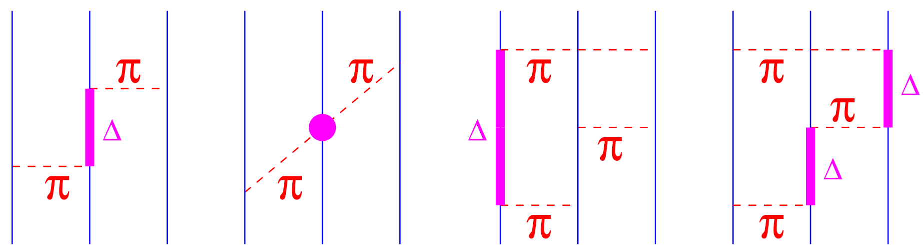
Argonne v$_{18}$: $v_{ij} = v^{\gamma}_{ij} + v^{\pi}_{ij} + v^{I}_{ij} + v^{S}_{ij} = \sum v_p(r_{ij}) O^p_{ij}$

- 18 spin, tensor, spin-orbit, isospin, etc., operators
- full EM and strong CD and CSB terms included
- predominantly local operator structure
- fits Nijmegen PWA93 data with $\chi^2$/d.o.f.=1.1




Wiringa, Stoks, & Schiavilla, PRC **51**, (1995)

Urbana & Illinois: $V_{ijk} = V^{2\pi}_{ijk} + V^{3\pi}_{ijk} + V^{R}_{ijk}$




- Urbana has standard $2\pi$ $P$-wave + short-range repulsion for matter saturation
- Illinois adds $2\pi$ $S$-wave + $3\pi$ rings to provide extra $T$=3/2 interaction
- Illinois-7 has four parameters fit to 23 levels in $A \leq 10$ nuclei

Pieper, Pandharipande, Wiringa, & Carlson, PRC **64**, 014001 (2001)

Pieper, AIP CP **1011**, 143 (2008)

Norfolk NV2: $v_{ij} = v^{\gamma}_{ij} + v^{\pi}_{ij} + v^{2\pi}_{ij} + v^{CT}_{ij} = \sum v_p(r_{ij}) O^p_{ij}$

- derived in chiral effective field theory with $\Delta$-intermediate states
- 17 spin, tensor, spin-orbit, isospin, etc., operators
- full EM and strong CD and CSB terms included
- predominantly local operator structure suitable for quantum Monte Carlo
- multiple models with different regularization fit to Granada PWA2013 data
- Ia,b,c fit to $E_{\rm lab}$ = 125 MeV with $\chi^2$/d.o.f.$\sim$1.1
- IIa,b,c fit to $E_{\rm lab}$ = 200 MeV with $\chi^2$/d.o.f.$\sim$1.4

Piarulli, Girlanda, Schiavilla, Kievsky, Lovato, Marcucci, Pieper, Viviani, & Wiringa, PRC **94**, 054007 (2016)

Norfolk NV3: $V_{ijk} = V^{2\pi}_{ijk} + V^{CT}_{ijk}$

- standard $2\pi$ $S$-wave and $2\pi$ $P$-wave terms consistent with chiral $NN$ potential
- contact terms of $c_D$ ($\pi$-short range) and $c_E$ (short-short range $\tau_i \cdot \tau_k$) type
- two parameters fit to $^3$H binding and $nd$ scattering length

Piarulli, Baroni, Girlanda, Kievsky, Lovato, Marcucci, Pieper, Schiavilla, Viviani, & Wiringa, PRL **120**, 052503 (2018)

# QUANTUM MONTE CARLO

Variational Monte Carlo (VMC): construct $\Psi_V$ that

- Are fully antisymmetric and translationally invariant
- Have cluster structure and correct asymptotic form
- Contain non-commuting 2- & 3-body operator correlations from $v_{ij}$ & $V_{ijk}$
- Are orthogonal for multiple $J^\pi$ states
- Minimize $E_V = \langle \Psi_V | H | \Psi_V \rangle \geq E$

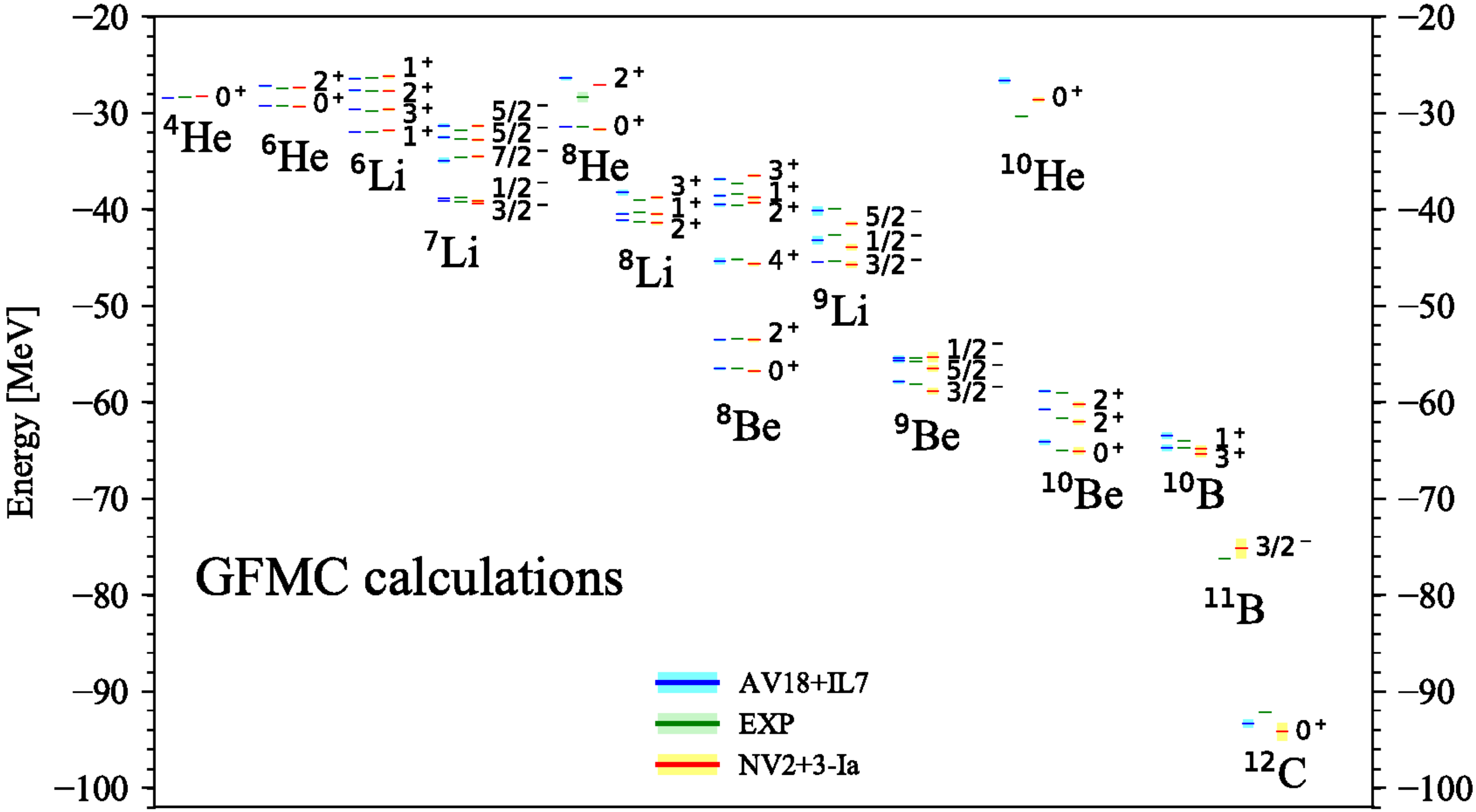
These are $\sim 2^A \binom{A}{Z}$ component (540,672 for $^{12}$C) spin-isospin vectors in $3A$ dimensions

Green's function Monte Carlo (GFMC): project out the exact eigenfunction

- $\Psi(\tau) = \exp[-(H - E_0)\tau]\Psi_V = \sum_n \exp[-(E_n - E_0)\tau] a_n \Psi_n \Rightarrow \Psi_0$ at large $\tau$
- Propagation done stochastically in small time slices $\Delta\tau$
- Exact $\langle H \rangle$ for local potentials; mixed estimates for other $\langle O \rangle$
- Constrained-path propagation controls fermion sign problem for $A \geq 8$
- Multiple excited states for same $J^\pi$ stay orthogonal

Many tests demonstrate 1–2% accuracy for realistic $\langle H \rangle$

Carlson, Gandolfi, Pederiva, Pieper, Schiavilla, Schmidt, & Wiringa, RMP **87**, 1067 (2015)




RMS $\Delta E$ for 36 states: AV18+IL7 = 0.80 MeV ; NV2+3-Ia = 0.72 MeV

with signed average deviation: -0.23 MeV and +0.15 MeV

# Nolen-Schiffer Anomaly

Nuclear forces are mostly charge-independent [CI $\propto 1, \tau_i \cdot \tau_j$ ], but have small charge-dependent [CD $\propto T_{ij}$] and charge-symmetry-breaking [CSB $\propto (\tau_i + \tau_j)_z$] components, while electromagnetic forces are a mix of CI, CD, & CSB terms. Evidence for strong charge-independence-breaking (CIB) comes from the energy differences of isobaric multiplets:

$$E_{A,T}(T_z) = \sum_{n \leq 2T} a_n(A,T) Q_n(T,T_z)$$

$$Q_0 = 1 \; ; \; Q_1 = T_z \; ; \; Q_2 = \tfrac{1}{2}(3T_z^2 - T^2)$$

For example,

$$a_1(3, \tfrac{1}{2}) = E(^3\mathrm{He}) - E(^3\mathrm{H}) \qquad a_2(6,1) = \tfrac{1}{3}[E(^6\mathrm{Be}) - 2E(^6\mathrm{Li}^*) + E(^6\mathrm{He})]$$

The Nolen-Schiffer anomaly is the difference not explained by Coulomb force; strong CIB and other electromagnetic terms in Argonne $v_{18}$ explain much of the remainder (shown in keV):

| $a_n(A,T)$ | $K^{CSB}$ | $v_{C1}(pp)$ | $v^{\gamma,R}$ | $v^{CSB}$ $+v^{CD}$ | $\delta H^{CI}$ | Total | Expt. |
|---|---|---|---|---|---|---|---|
| $a_1(3, \frac{1}{2})$ | 14 | 642(1) | 26 | 65(0) | 8(1) | 755(1) | 764 |
| $a_1(7, \frac{1}{2})$ | 23 | 1442(2) | 36 | 83(1) | 27(10) | 1611(10) | 1645 |
| $a_1(8,1)$ | 25 | 1652(3) | 18 | 77(1) | 33(11) | 1813(11) | 1770 |
| $a_2(6,1)$ | | 140(1) | 18 | 100(2) | 17(2) | 273(3) | 223 |
| $a_2(8,1)$ | | 133(1) | 3 | −3(2) | 10(5) | 139(5) | 127 |

# Isospin-mixing in $^{8}$Be

Experimental energies of $2^+$ states

$E_a$ = 16.626(3) MeV $\Gamma_a^\alpha$ = 108.1(5) keV

$E_b$ = 16.922(3) MeV $\Gamma_b^\alpha$ = 74.0(4) keV

Isospin mixing of $2^+$;1 and $2^+$;0* states due to isovector interaction $H_{01}$:

$\Psi_a = \beta\Psi_0 + \gamma\Psi_1$ ; $\Psi_b = \gamma\Psi_0 - \beta\Psi_1$

decay through $T = 0$ component only

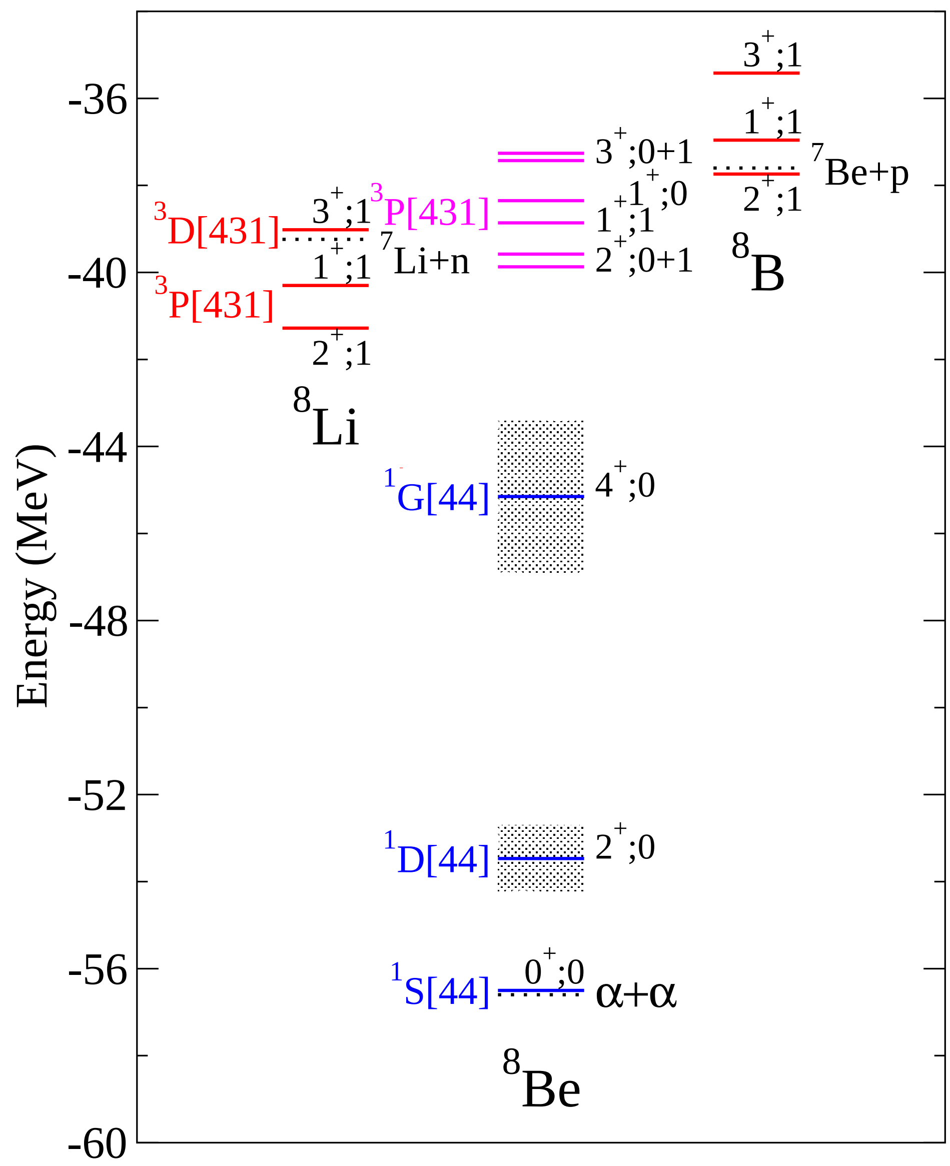
$\Gamma_a^\alpha / \Gamma_b^\alpha = \beta^2/\gamma^2 \Rightarrow \beta = 0.77$ ; $\gamma = 0.64$

$$E_{a,b} = \frac{H_{00} + H_{11}}{2} \pm \sqrt{\left(\frac{H_{00} - H_{11}}{2}\right)^2 + (H_{01})^2}$$

$H_{00} = 16.746(2)$ MeV

$H_{11} = 16.802(2)$ MeV

$H_{01} = -145(3)$ keV



Isospin-mixing matrix elements in keV

| | $K^{CSB}$ | $v_{C1}(pp)$ | $v^{\gamma,R}$ | $v^{CSB}$+$v^{CD}$ | $H_{01}$ | Expt. |
|---|---|---|---|---|---|---|
| $2^+;1 \Leftrightarrow 2_2^+;0$ | $-3.6(1)$ | $-89.3(11)$ | $-11.0(2)$ | $-23.4(4)$ | $-127(2)$ | $-145(3)$ |
| $1^+;1 \Leftrightarrow 1^+;0$ | $-2.8(1)$ | $-73.4(11)$ | $1.0(1)$ | $-18.5(4)$ | $-94(1)$ | $-103(14)$ |
| $3^+;1 \Leftrightarrow 3^+;0$ | $-3.0(1)$ | $-74.6(12)$ | $-16.8(2)$ | $-16.6(4)$ | $-111(2)$ | $-59(12)$ |
| $2^+;1 \Leftrightarrow 2_1^+;0$ | | | | | $-7(2)$ | |
| $0^+;2 \Leftrightarrow 0_3^+;0$ | | $-32.2(2)$ | $-8.9(1)$ | $-83.8(22)$ | $-125(2)$ | |

Coulomb terms are 70% of $H_{01}$, but magnetic moment and strong Type III CSB are relatively more important than in Nolen-Schiffer anomaly; still missing $\approx 10\%$ of strength.

Strong Type IV CSB also contribute (probably best nuclear structure place to look):

$$V_{IV}^{CSB} = (\tau_1 - \tau_2)_z(\sigma_1 - \sigma_2)\cdot\mathbf{L}\, v(r) + (\tau_1 \times \tau_2)_z(\sigma_1 \times \sigma_2)\cdot\mathbf{L}\, w(r)$$

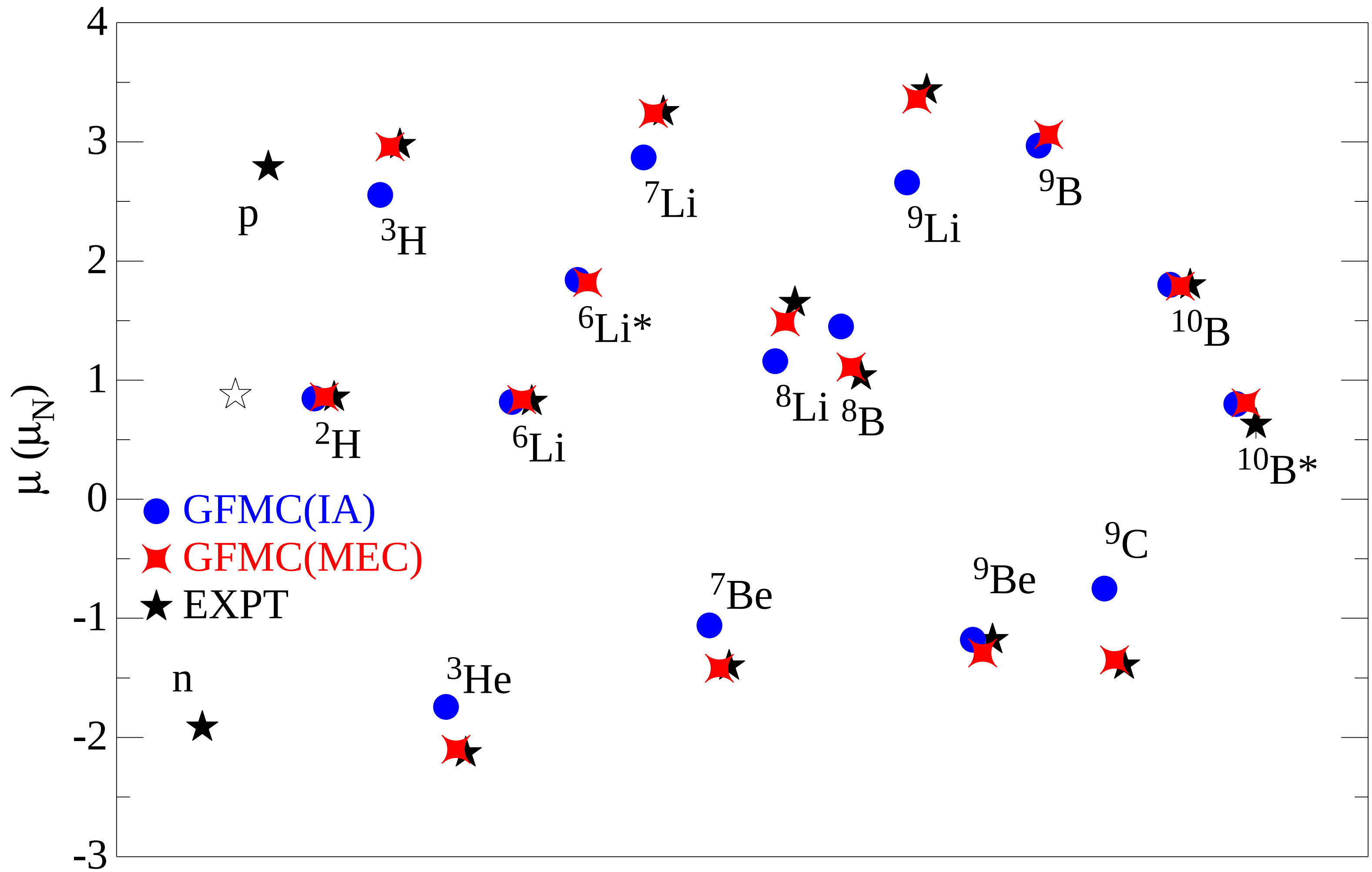
These contributions are model-dependent with $V_{IV}^{CSB} \sim \pm$ few keV.

Wiringa, Pastore, Pieper, & Miller, Phys. Rev. C **88**, 044333 (2013)

# $A \leq 10$ Magnetic moments w/ $\chi$EFT exchange currents

Hybrid calculations using AV18+IL7 wave functions and $\chi$EFT exchange currents developed in:

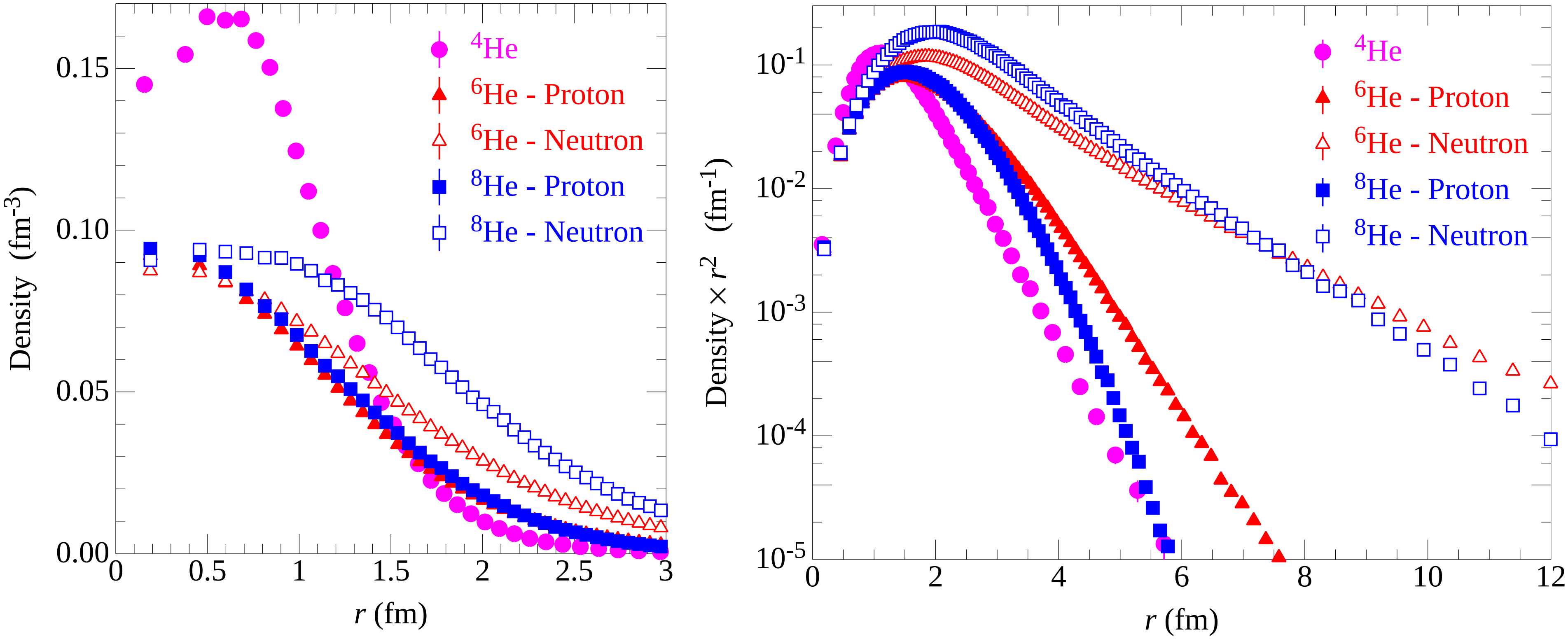
Pastore, Schiavilla, & Goity, PRC **78**, 064002 (2008) ; Pastore, *et al.*, PRC **80**, 034004 (2009)




Pastore, Pieper, Schiavilla & Wiringa, PRC **87**, 035503 (2013)

# SINGLE-NUCLEON DENSITIES

$$\rho_{p,n}(r) = \sum_i \langle \Psi | \delta(r - r_i) \frac{1 \pm \tau_i}{2} | \Psi \rangle$$




RMS radii

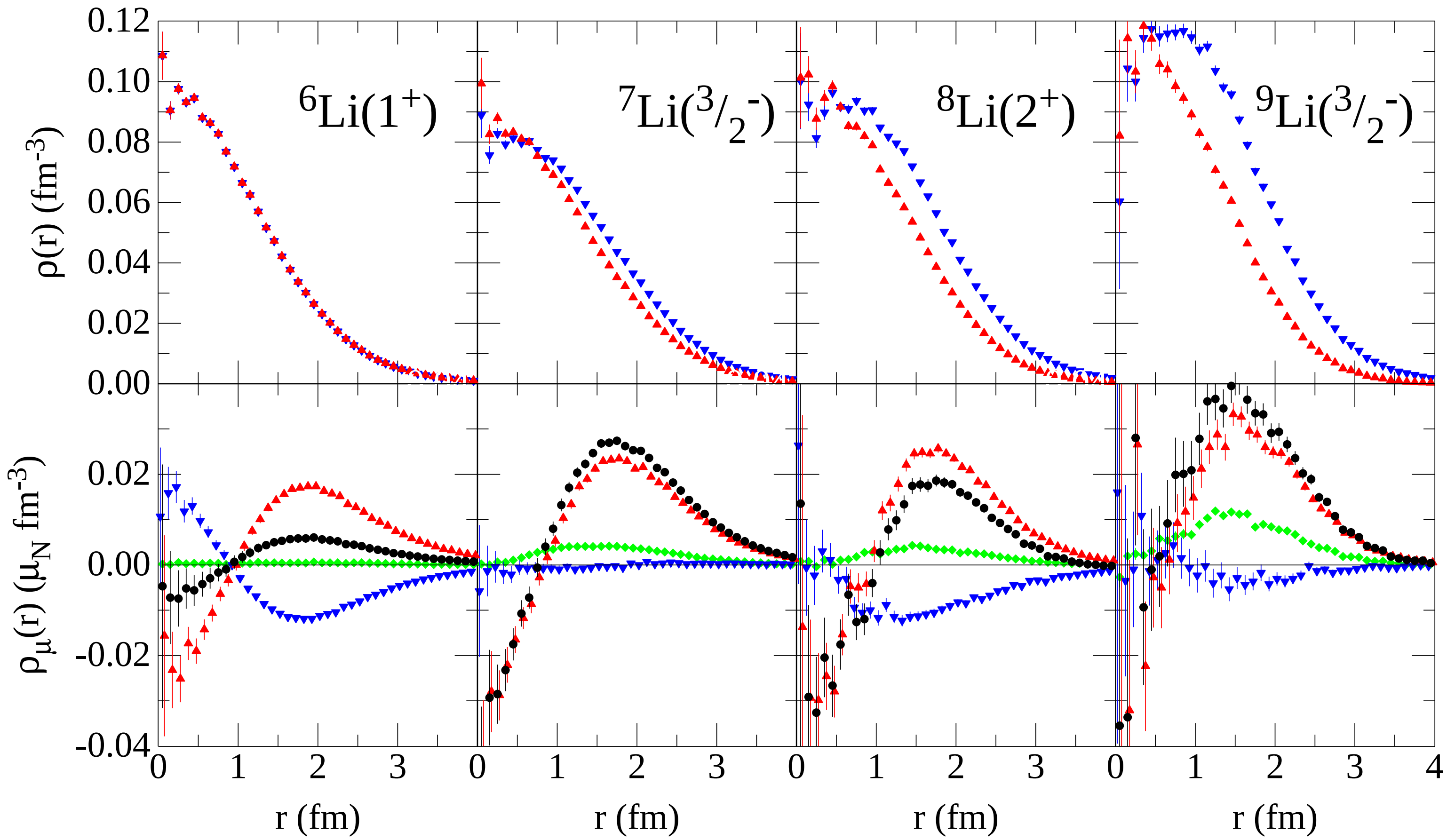
| | $r_n$ | $r_p$ | $r_c$ | Expt |
|---|---|---|---|---|
| $^4$He | 1.45(1) | 1.45(1) | 1.67(1) | 1.681(4)* |
| $^6$He | 2.86(6) | 1.92(4) | 2.06(4) | 2.060(8)† |
| $^8$He | 2.79(3) | 1.82(2) | 1.94(2) | 1.959(16)‡ |


*Sick, PRC **77**, 041302(R) (2008)

†Wang, *et al.*, PRL **93**, 142501 (2004)

‡Mueller, *et al.*, PRL **99**, 252501 (2007)

Brodeur, *et al.*, PRL **108**, 052504 (2012)




RMS radii

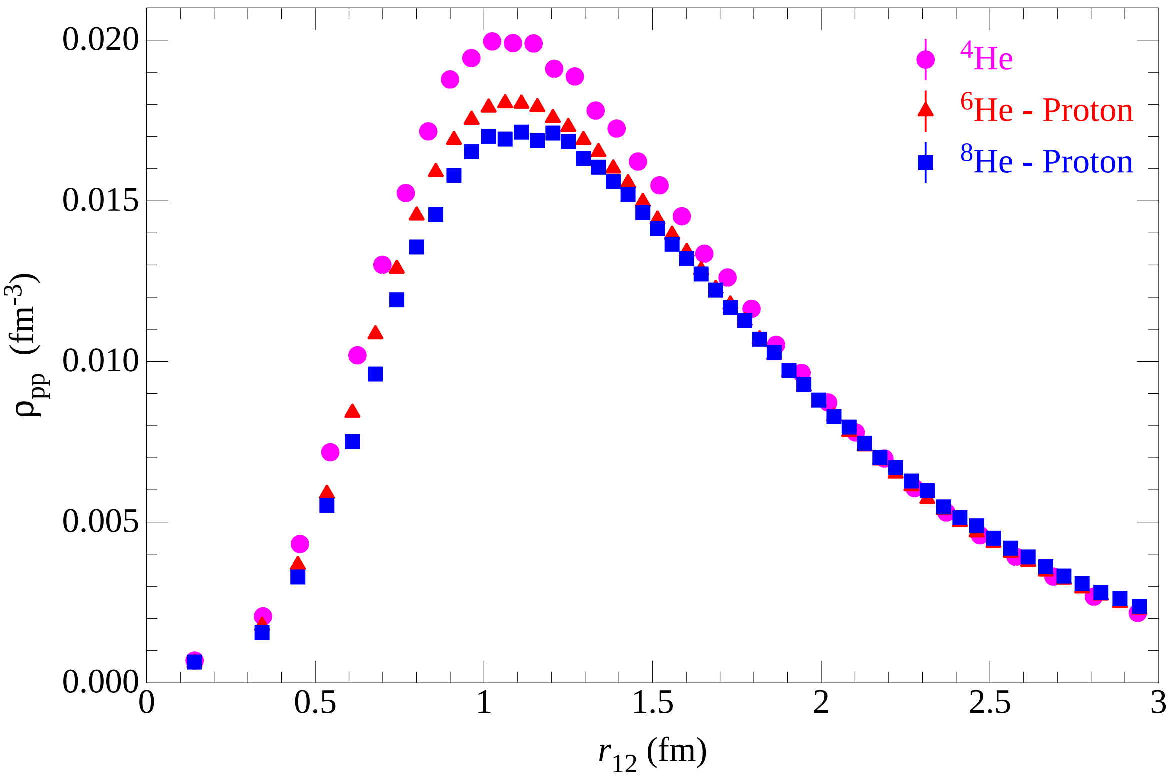
| | $r_c$ | Expt | $r_m$ | Expt |
|---|---|---|---|---|
| $^6$Li | 2.53(1) | 2.589(39)* | 3.30(2) | |
| $^7$Li | 2.38(1) | 2.444(43)* | 2.86(2) | 2.98(5) † |
| $^8$Li | 2.24(1) | 2.339(45)* | 1.85(2) | |
| $^9$Li | 2.10(1) | 2.245(47)* | 2.38(2) | |

* Nörtershauser, *et al.*, PRC **84**, 024307(R) (2011)

†Van Niftrik, *et al.*, NPA **174**, 173 (1971)

# TWO-NUCLEON DENSITIES

$$\rho_{pp}(r) = \sum_{i<j} \langle \Psi | \delta(r - |\mathbf{r}_i - \mathbf{r}_j|) \frac{1+\tau_i}{2} \frac{1+\tau_j}{2} | \Psi \rangle$$




RMS radii

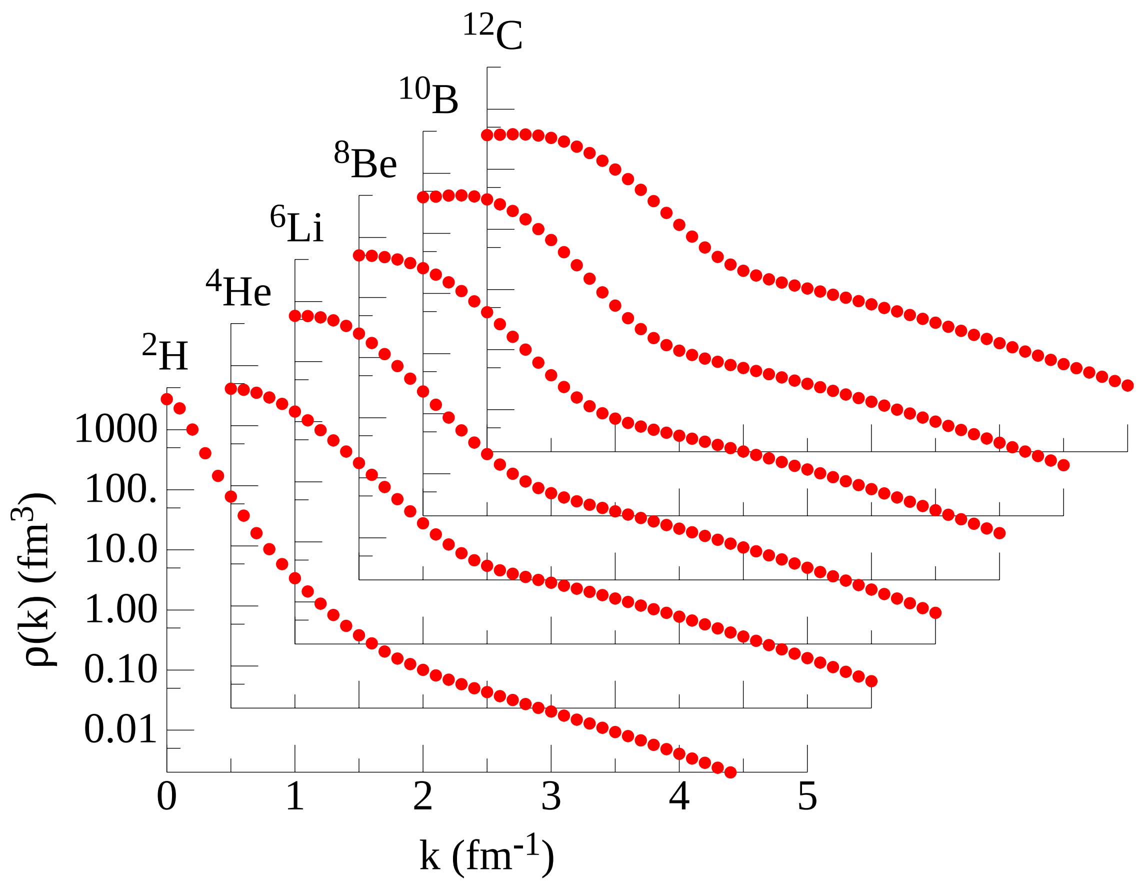
| | $r_{pp}$ | $r_{np}$ | $r_{nn}$ |
|---|---|---|---|
| $^4$He | 2.41 | 2.35 | 2.41 |
| $^6$He | 2.51 | 3.69 | 4.40 |
| $^8$He | 2.52 | 3.58 | 4.37 |

# SINGLE-NUCLEON MOMENTUM DISTRIBUTIONS

Probability of finding a nucleon in a nucleus with momentum $k$ in a given spin-isospin state:

$$\rho_{\sigma\tau}(k) = \int d\mathbf{r}'_1 d\mathbf{r}_1 d\mathbf{r}_2 \cdots d\mathbf{r}_A \, \psi^\dagger_A(\mathbf{r}'_1, \mathbf{r}_2, \ldots, \mathbf{r}_A) \, e^{-i\mathbf{k}\cdot(\mathbf{r}_1 - \mathbf{r}'_1)} \, P_{\sigma\tau} \, \psi_A(\mathbf{r}_1, \mathbf{r}_2, \ldots, \mathbf{r}_A)$$

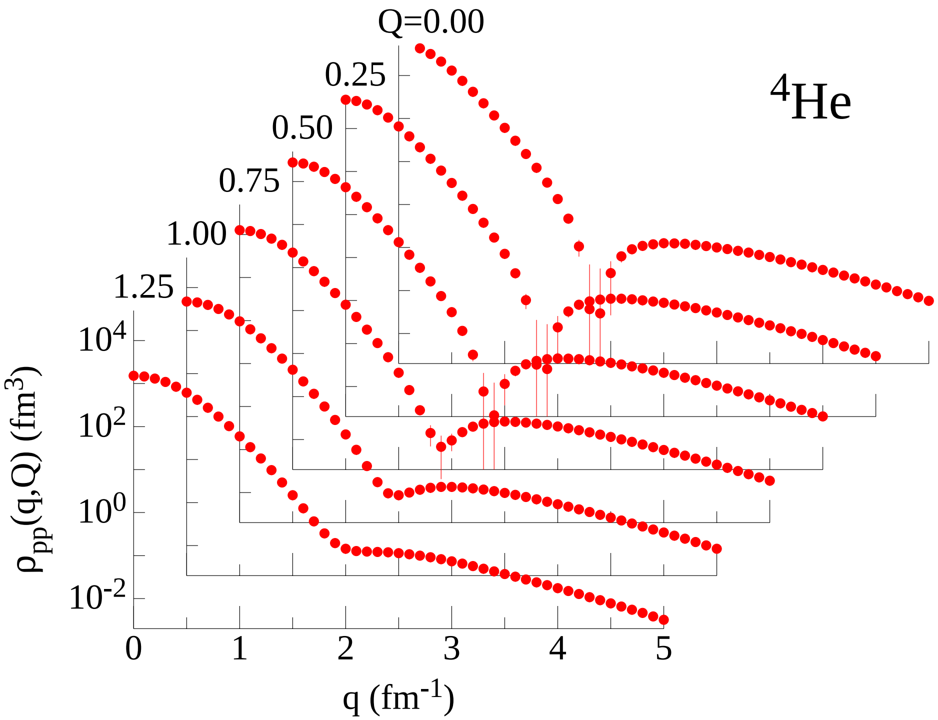
- Useful input for electron scattering studies
- Universal character of high-momentum tails from $np$ tensor interaction

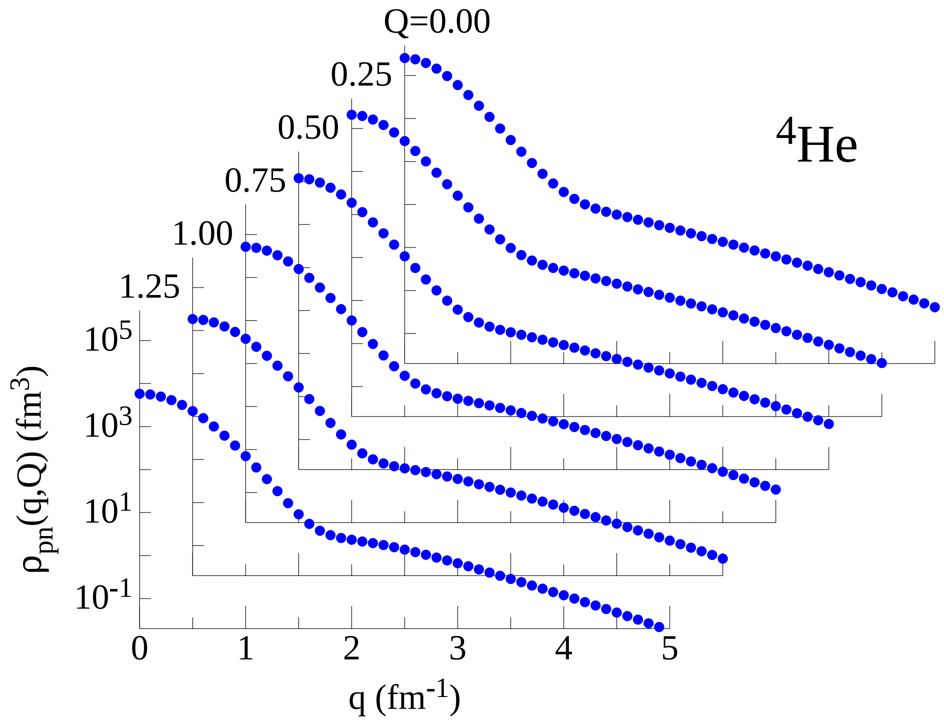



Wiringa, Schiavilla, Pieper, & Carlson, PRC **89**, 024305 (2014)

# Two-nucleon momentum distributions

Probability $\rho_{NN}(q,Q)$ of finding a pair of nucleons with relative momentum $q$ and total momentum $Q$ can be defined in a similar fashion:




- Large ratio $\rho_{pn}(q,Q=0)$ / $\rho_{pp}(q,Q=0)$ has been observed in $^{12}$C$(e,e'pN)$ scattering
- Results in good agreement with recent $^{4}$He$(e,e'pN)$ experiment

Korover, *et al.* (JLab Hall A), PRL **113**, 022501 (2014)

# $M1$, $E2$, F, GT transitions

NO EFFECTIVE CHARGES!

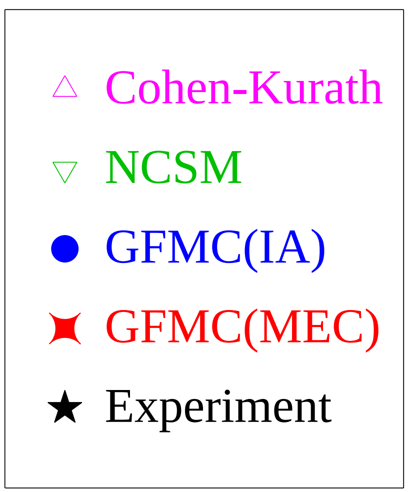
$$E2 = e\sum_k \tfrac{1}{2}\left[r_k^2 Y_2(\hat{r}_k)\right](1+\tau_{kz})$$

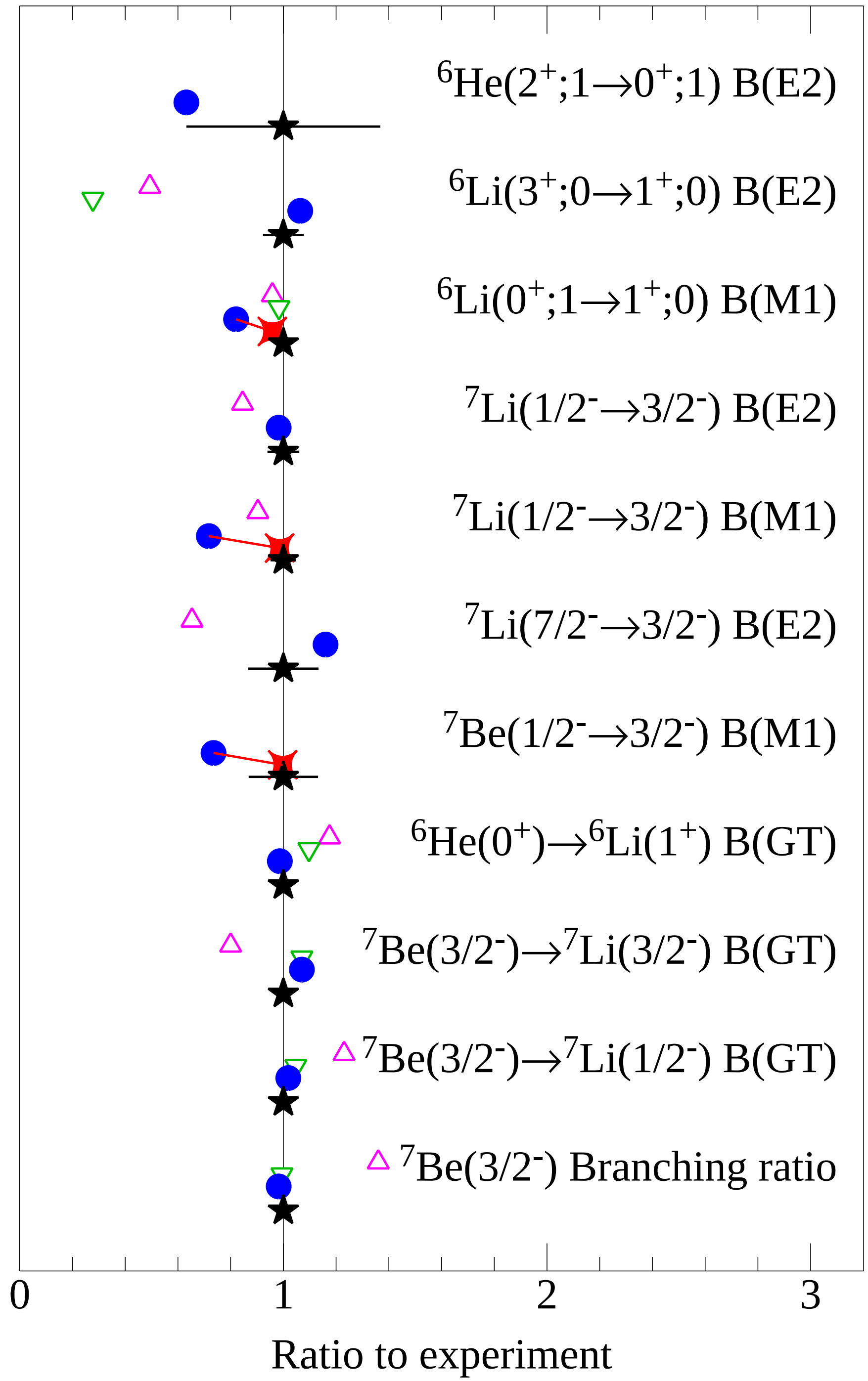
$$M1 = \mu_N \sum_k [(L_k + g_p S_k)(1+\tau_{kz})/2 + g_n S_k \; (1-\tau_{kz})/2]$$

$$\mathrm{F} = \sum_k \tau_{k\pm} \;\; ; \;\; \mathrm{GT} = \sum_k \sigma_k \tau_{k\pm}$$

Pervin, Pieper, & Wiringa, PRC **76**, 064319 (2007)

Marcucci, Pervin, *et al.*, PRC **78**, 065501 (2008)



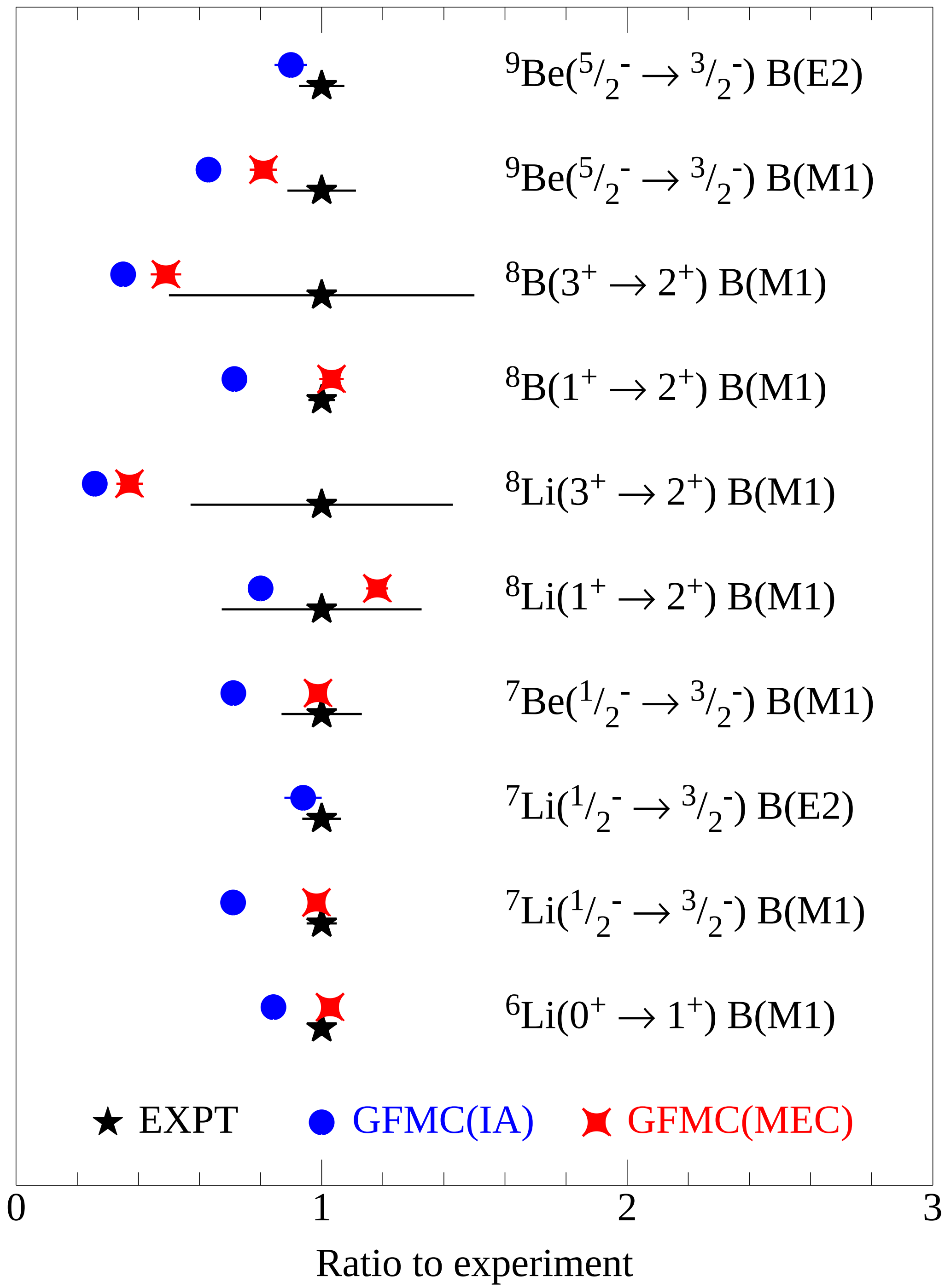



# $M1$ TRANSITIONS W/ $\chi$EFT

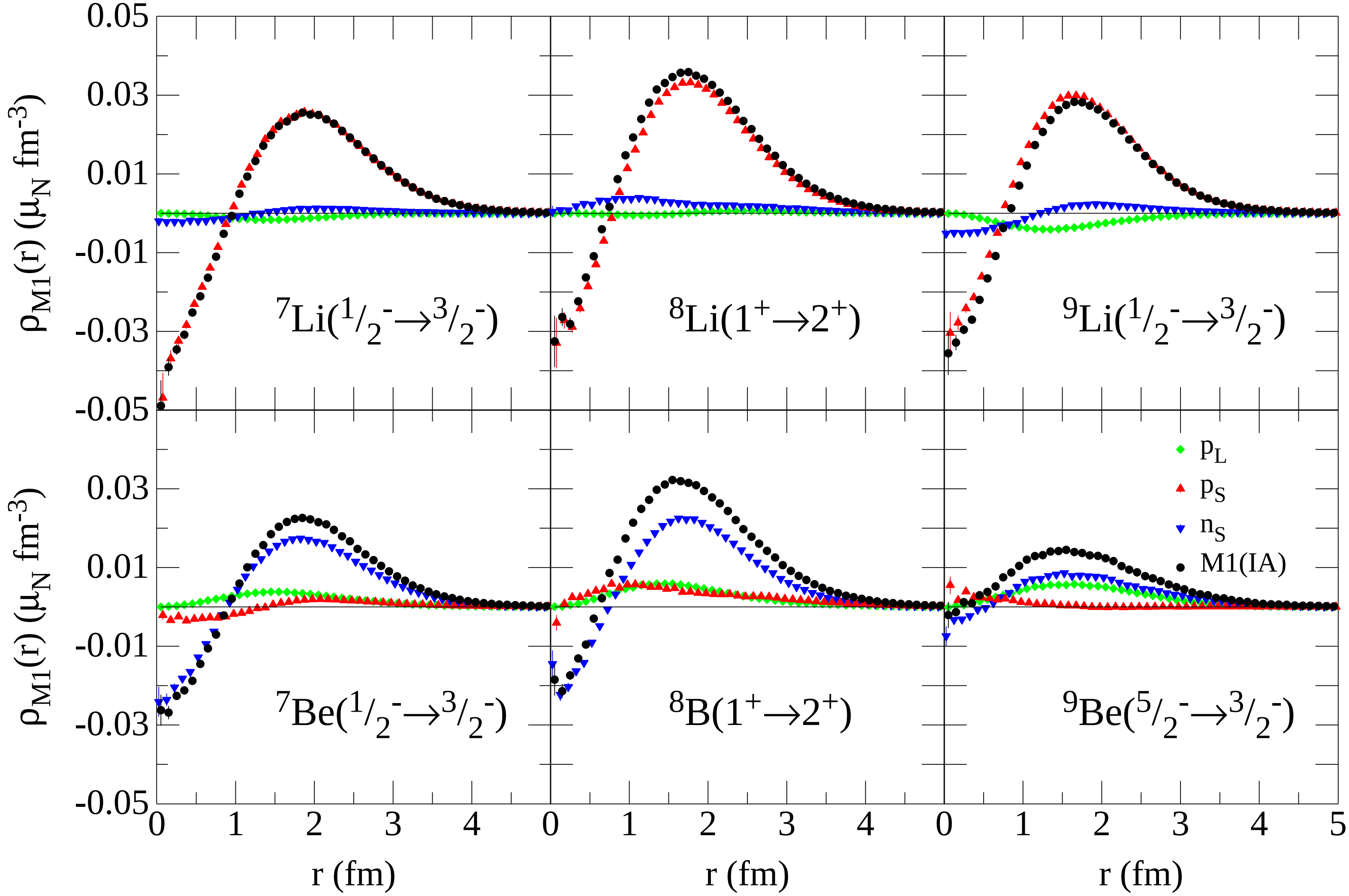
- dominant contribution is from OPE
- five LECs at N3LO
- $d_2^V$ and $d_1^V$ are fixed assuming $\Delta$ resonance saturation
- $d^S$ and $c^S$ are fit to experimental $\mu_d$ and $\mu_S(^3\mathrm{H}/^3\mathrm{He})$
- $c^V$ is fit to experimental $\mu_V(^3\mathrm{H}/^3\mathrm{He})$
- $\Lambda = 600$ MeV

Pastore, Pieper, Schiavilla, & Wiringa

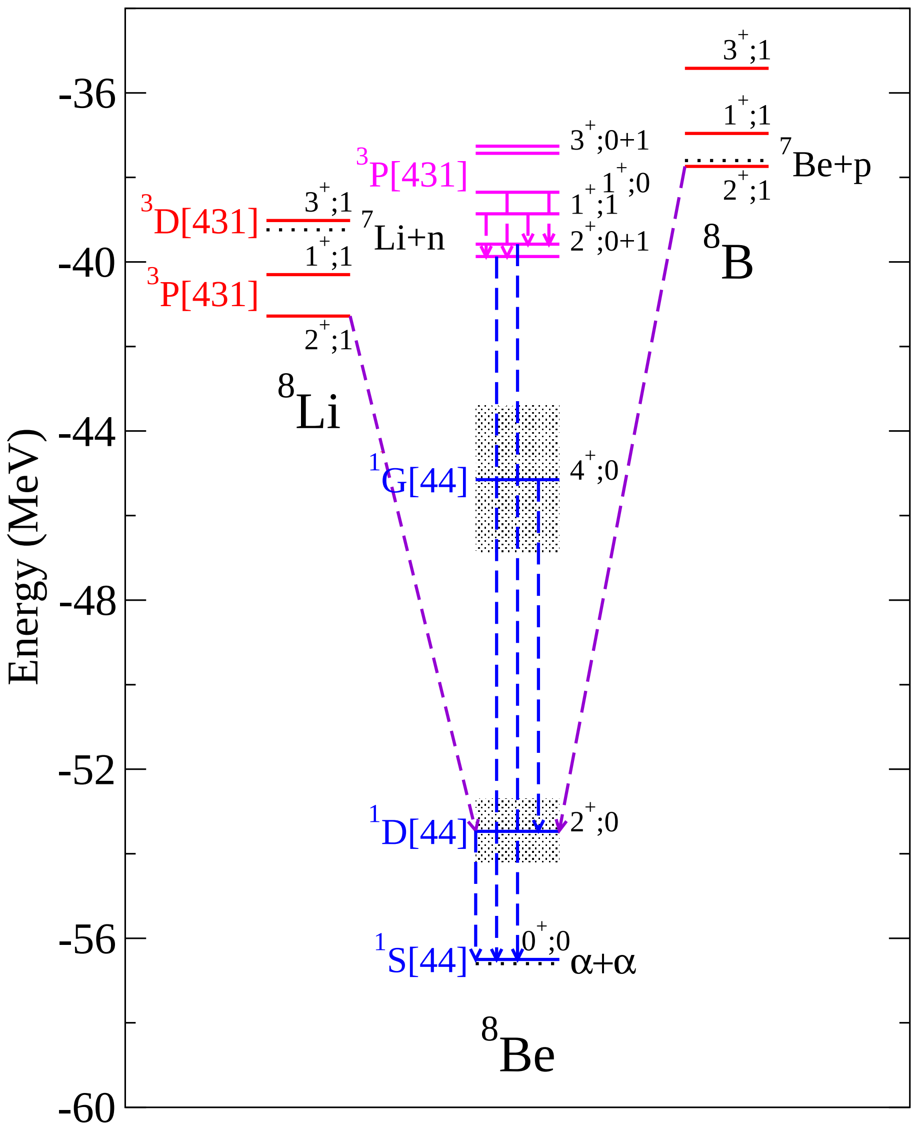
PRC **87**, 035503 (2013)



# M1 TRANSITION DENSITIES




$\mu_p[\rho_{p\uparrow}(r) - \rho_{p\downarrow}(r)]$ $\mu_n[\rho_{n\uparrow}(r) - \rho_{n\downarrow}(r)]$ $\mu_p \rho_{p\mathbf{L}}(r)$



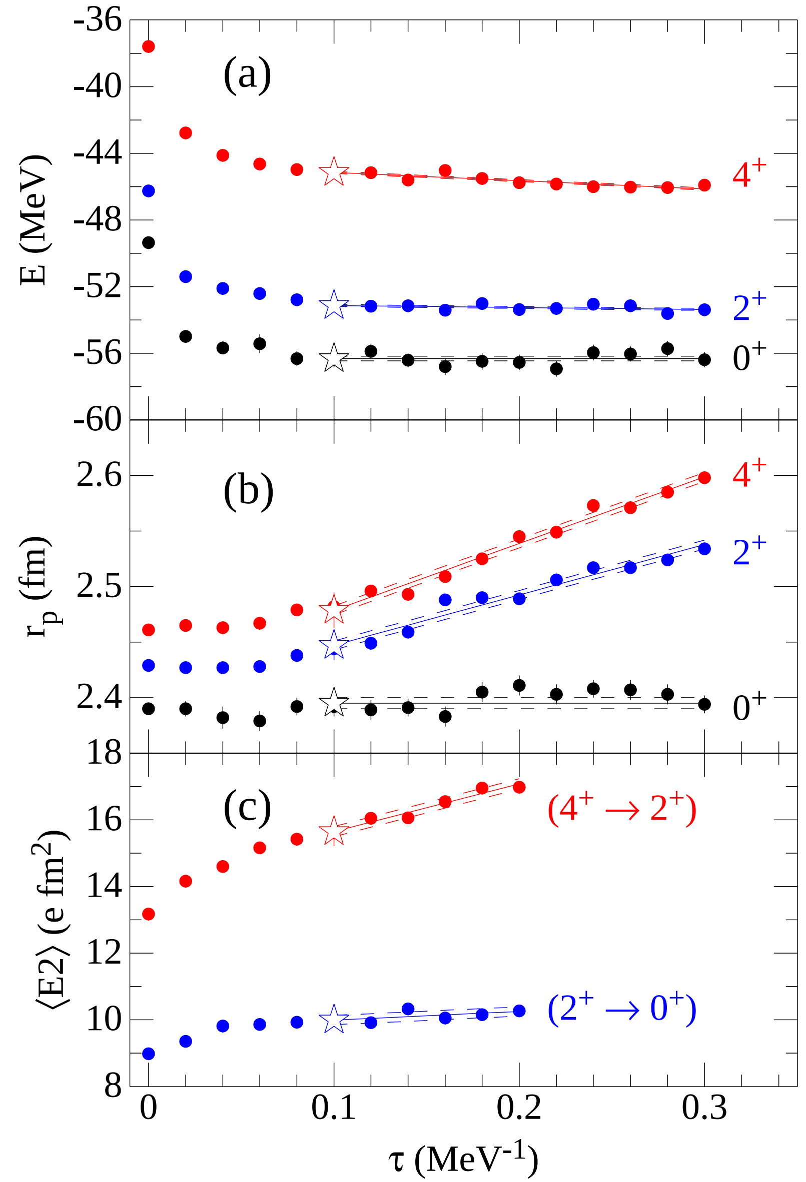

# TRANSITIONS IN/TO $^8$Be

- $^8$Be presents new challenges in transition calculations
- $E2$ transitions between rotational band states which have large widths
- $M1$ transitions involving isospin-mixed states
- $GT$ transitions that are not super-allowed and go to a broad final state

| $J^\pi; T$ | GFMC | Expt |
|---|---|---|
| $0^+$ | -56.3(2) | -56.50 |
| $2^+$ | + 3.2(2) | + 3.03(1) |
| $4^+$ | +11.2(2) | +11.35(15) |
| $2^+; 0$ | +16.8(3) | +16.746(3) $\longrightarrow$ 16.626 |
| $2^+; 1$ | +16.8(3) | +16.802(3) $\longrightarrow$ 16.922 |
| $1^+; 1$ | +17.4(2) | +17.66(1) $\longrightarrow$ 17.64 |
| $1^+; 0$ | +18.0(3) | +18.13(1) $\longrightarrow$ 18.15 |

# $E2$ TRANSITIONS IN $^{8}$Be

- New experiment at Tata Institute, Mumbai for $4^+ \rightarrow 2^+$ transition
- Experimental AND theoretical challenge: $4^+$ and $2^+$ states are wide and breakup into two $\alpha$s
- GFMC calculation is extrapolated back to $\tau = 0.1$ MeV$^{-1}$; predicts $B(E2)$ = 27.2(15)
- Experiment detects $\alpha$+$\alpha$+$\gamma$ in coincidence for range of beam energies
- Assuming Breit-Wigner shape, simple analysis gives $B(E2)$ = 21.3(23)




Datar, Chakrabarty, Kumar, Nanal, Pastore, Wiringa, et al., PRL **111**, 062502 (2013)

# $M1$ TRANSITIONS IN $^{8}$Be BETWEEN ISOSPIN-MIXED STATES

We calculate between states of pure isospin:

| matrix element | IA | MEC | TOT |
|---|---|---|---|
| $\langle 1^+;1\|M1\|2^+;0\rangle$ | 2.29(1) | 0.62(1) | 2.91(1) |
| $\langle 1^+;1\|M1\|2^+;1\rangle$ | 0.14(0) | 0.04(1) | 0.18(1) |
| $\langle 1^+;0\|M1\|2^+;0\rangle$ | 0.17(0) | 0.02(0) | 0.19(0) |
| $\langle 1^+;0\|M1\|2^+;1\rangle$ | 2.60(1) | 0.29(1) | 2.89(1) |

Then have to combine them using the physical states:

$$|16.626\rangle = 0.77|2^+;0\rangle + 0.64|2^+;1\rangle \qquad |17.64\rangle = 0.24|1^+;0\rangle + 0.97|1^+;1\rangle$$

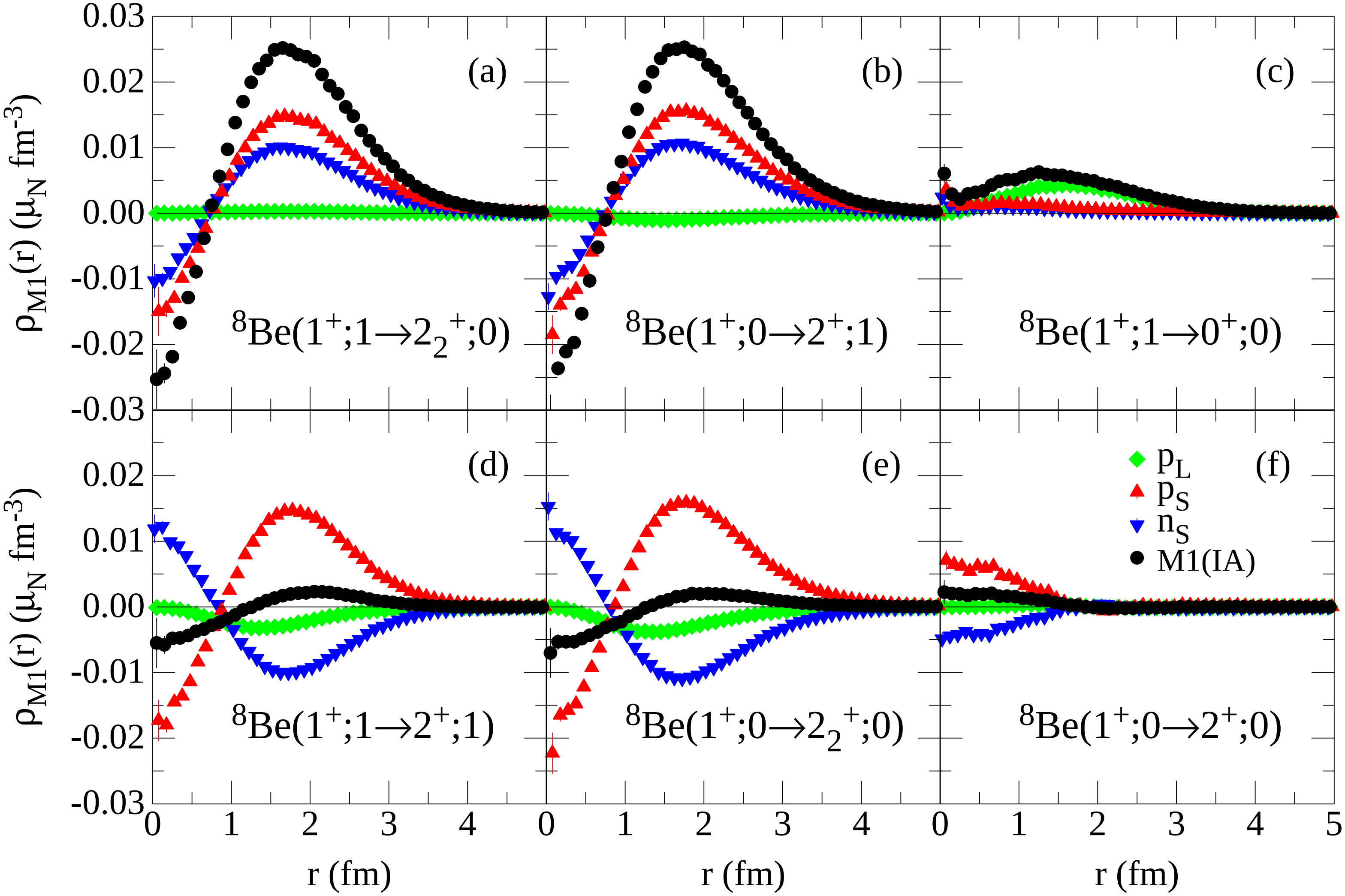
$$|16.922\rangle = 0.64|2^+;0\rangle - 0.77|2^+;1\rangle \qquad |18.15\rangle = 0.97|1^+;0\rangle - 0.24|1^+;1\rangle$$

to get the final results:

| $B(M1)$ | IA | TOT | Expt |
|---|---|---|---|
| 17.64 $\longrightarrow$ 16.626 | 1.65(2) | 2.54(3) | 2.65(25) |
| 17.64 $\longrightarrow$ 16.922 | 0.25(1) | 0.46(1) | 0.30(7) |
| 18.15 $\longrightarrow$ 16.626 | 0.56(1) | 0.62(1) | 1.88(46) |
| 18.15 $\longrightarrow$ 16.922 | 1.56(2) | 2.01(2) | 2.89(33) |

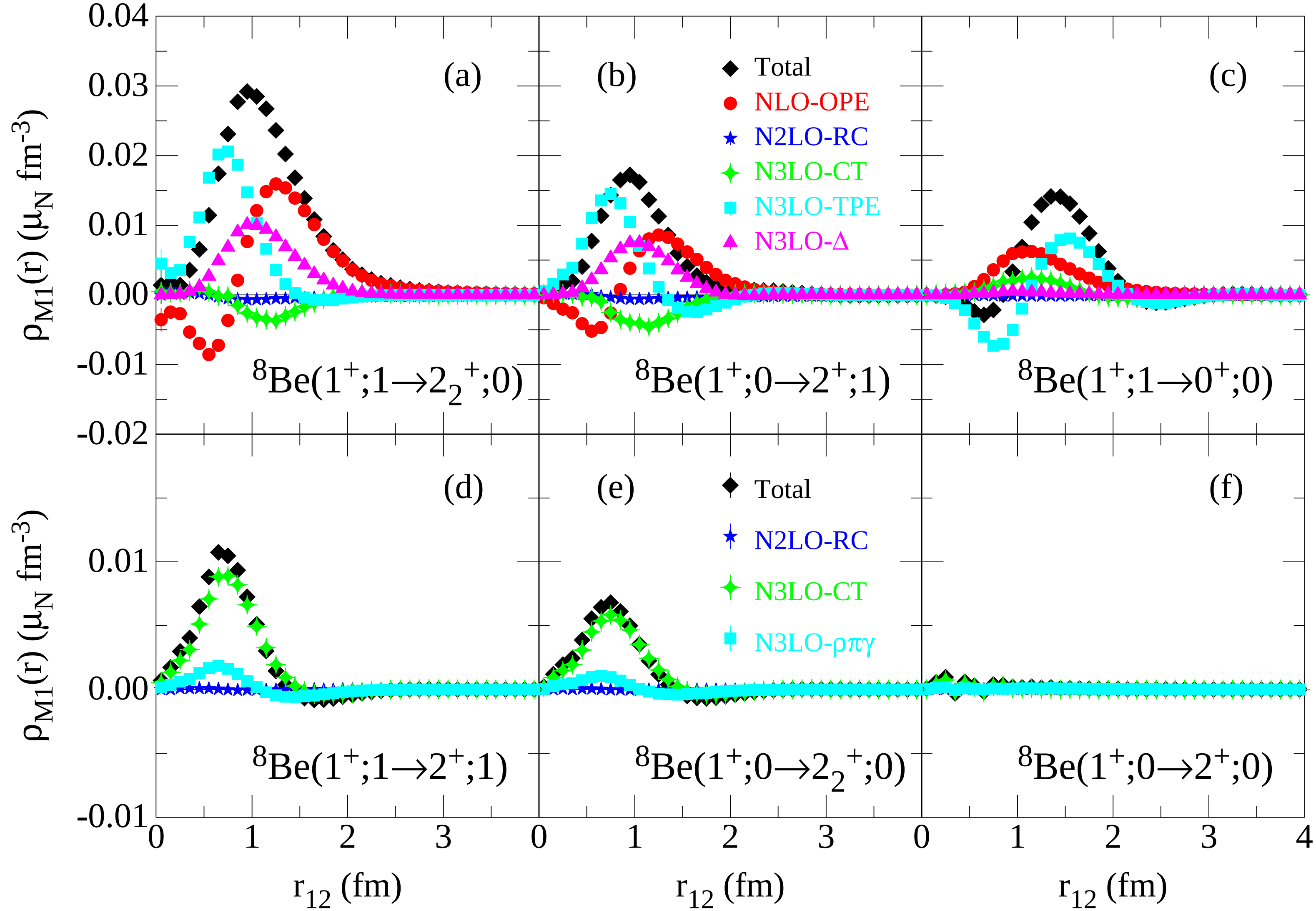
We evaluate the isospin-mixing matrix elements $\langle H_{01}\rangle$ to make sure we have the correct relative signs of our wave functions.

# M1 TRANSITION DENSITIES - IMPULSE APPROXIMATION



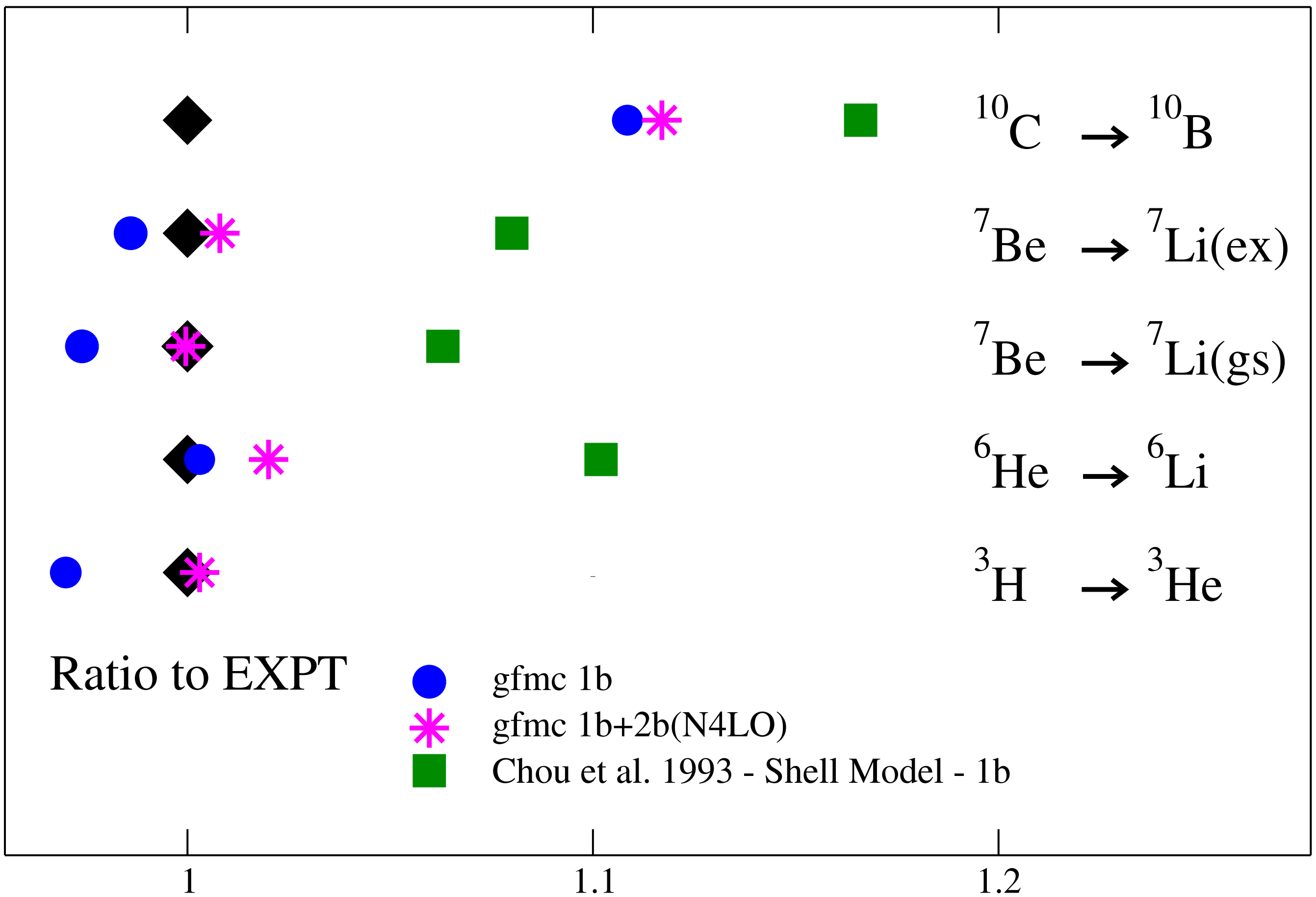

$\mu_p[\rho_{p\uparrow}(r) - \rho_{p\downarrow}(r)]$ $\mu_n[\rho_{n\uparrow}(r) - \rho_{n\downarrow}(r)]$ $\mu_p \rho_{p\mathbf{L}}(r)$

# M1 TRANSITION DENSITIES - TWO-BODY CURRENTS



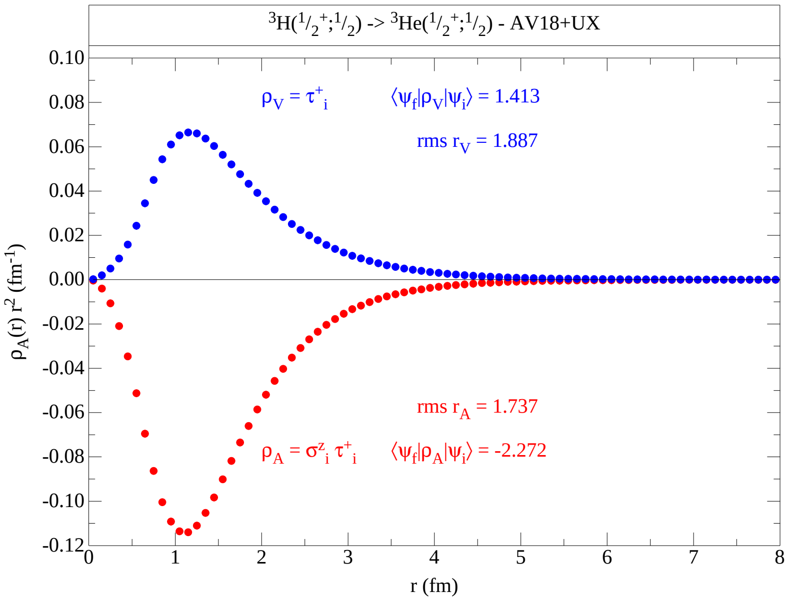

Pastore, Wiringa, Pieper, & Schiavilla, PRC **90**, 024321 (2014)

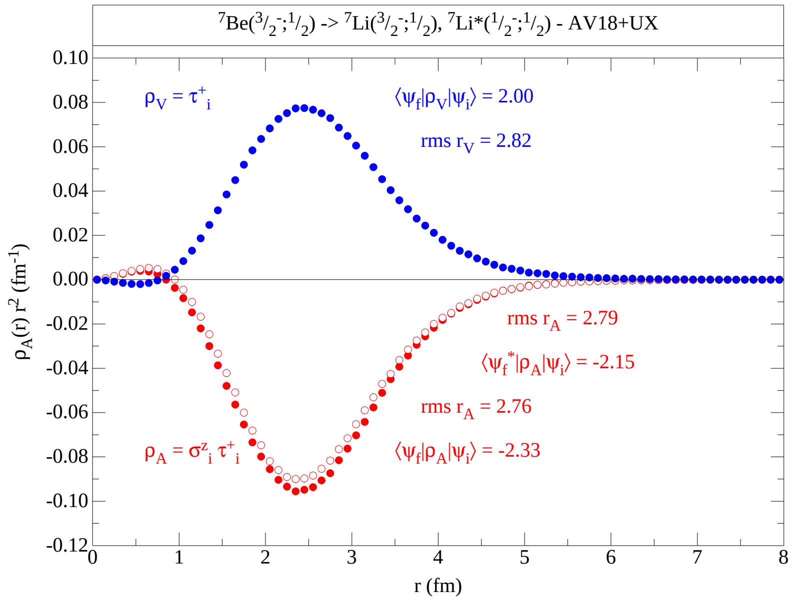
# WEAK DECAYS

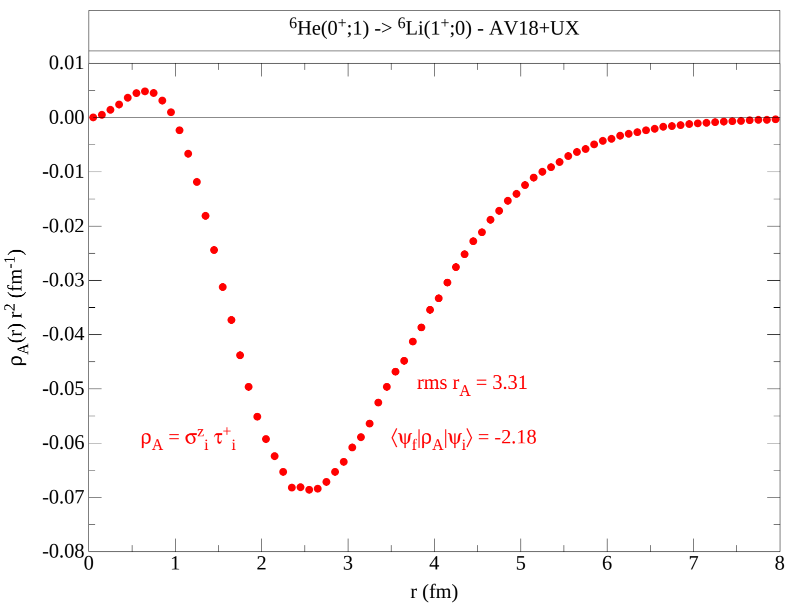


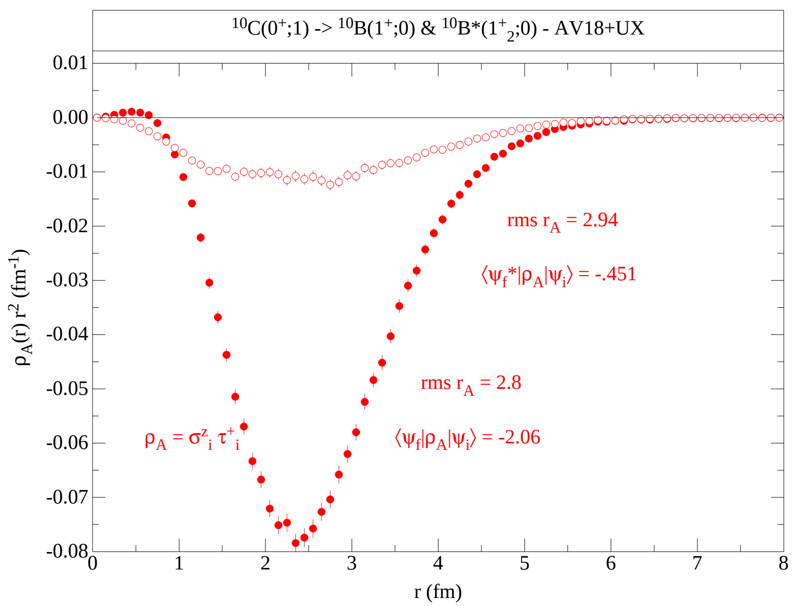

Pastore, Baroni, Carlson, Gandolfi, Pieper, Schiavilla, & Wiringa, PRC **97**, 022501 (2018)

# Weak transition densities



# Observations and ongoing work

- The $T_i + v_{ij}$ for AV18 and all NV2 underbind light nuclei so need net attraction from $V_{ijk}$
- AV18 and all NV2 saturate symmetric nuclear matter (SNM) at $\approx 2\rho_0$ so SNM needs net repulsion from $V_{ijk}$
- The $V_{ijk}^{2\pi}$ is attractive in nuclei and SNM, but weakly repulsive in pure neutron matter (PNM), so saturation in SNM and robust PNM need signficant repulsion from shorter-range $c_D$ and $c_E$
- The sign of NV3 $c_D$ term is not well determined by binding energy alone; new fits to GT matrix element give all NV3 $c_D^* < 0$ which provides repulsion in nuclei and SNM; in PNM its effect is much smaller due to weaker tensor correlations
- The $\langle \tau_i \cdot \tau_k \rangle$ of NV3 $c_E$ term is negative in light nuclei, but will change sign in PNM; new GT fits have small $c_E < 0$ ($> 0$) for soft -Ia, -IIa (hard -Ib, -IIb) giving weak repulsion (attraction) in nuclei
- Calculations of light nuclear spectra, SNM, PNM for new NV2+3$^*$ models are in progress, but more general 3NF may be required
- Set of 10 subleading chiral 3NF terms are being evaluated; also more general Urbana with $c_D$-like and multiple operator $c_E$-like terms
- Surveys of magnetic moments, $M1$, $E2$, and GT matrix elements in impulse approximation to check for possible problems are ongoing:

# VMC IA magnetic moments for NV2+3 potentials

| Nucleus | AV18+UX | NV2+3-Ia | NV2+3-Ib | NV2+3-IIa | NV2+3-IIb | Expt |
|---|---|---|---|---|---|---|
| 2H(1+) | 0.8470 | 0.8499 | 0.8485 | 0.8501 | 0.8501 | 0.8574 |
| 3H(1/2+) | 2.5901 | 2.5854 | 2.5886 | 2.5874 | 2.5895 | 2.9790 |
| 3He(1/2+) | -1.7753 | -1.7642 | -1.7723 | -1.7687 | -1.7687 | -2.1270 |
| 6Li(1+) | 0.8211 | 0.8245 | 0.8173 | 0.8233 | 0.8228 | 0.8220 |
| 7Li(3/2-) | 2.8999 | 2.9149 | | 2.8982 | | 3.2564 |
| 7Be(3/2-) | -1.0773 | -1.0863 | | -1.0701 | | -1.3980 |
| 8Li(2+) | 1.2576 | 1.3296 | 1.1743 | 1.2545 | 1.3186 | 1.6536 |
| 8B(2+) | 1.3319 | 1.2890 | | 1.3478 | 1.2967 | 1.0355 |
| 9Li(3/2-) | 2.7522 | 2.3664 | | 2.9109 | | 3.4391 |
| 9C(3/2-) | -0.7556 | -0.1988 | | -1.0979 | | -1.3914 |
| 9Be(3/2-) | -1.0957 | -0.9622 | | -1.0211 | | -1.1778 |
| 9B(3/2-) | 2.9415 | 2.6904 | | 2.7803 | | |
| 10B(3+) | 1.8047 | 1.7869 | | 1.7933 | | 1.8006 |
| 10B(1+) | 0.7893 | 0.7863 | | 0.8100 | | 0.6300 |
| 11B(3/2-) | 2.9125 | 1.9414 | | 2.1873 | | 2.6886 |
| 11C(3/2-) | | -0.3094 | | -0.5018 | | -0.9640 |

# VMC IA Gamow-Teller MEs for NV2+3 potentials

| Nucleus | AV18+UX | NV2+3-Ia | NV2+3-Ib | NV2+3-IIa | NV2+3-IIb | Expt | |
|---|---|---|---|---|---|---|---|
| | | | | | | Suzuki | Chou |
| 6He -> 6Li<br>0+;1 -> 1+;0 | 2.193 | 2.200 | 2.254 | 2.206 | 2.213 | 2.182 | 2.174 |
| 7Be -> 7Li<br>3/2- -> 3/2- | 2.335 | 2.318 | 2.294 | 2.294 | 2.309 | 2.290 | 2.280 |
| 7Be -> 7Li*<br>3/2- -> 1/2- | 2.150 | 2.158 | 2.120 | 2.127 | 2.143 | 2.128 | 2.119 |
| 8He -> 8Li*<br>0+;1 -> 1+;1 | 0.342 | 0.386 | | 0.467 | | 0.514 | 0.512 |
| 8Li -> 8Be*<br>2+;1 -> 2+;0 | 0.082 | 0.147 | | 0.144 | | | 0.288 |
| 8B -> 8Be*<br>2+;1 -> 2+;0 | 0.082 | 0.146 | | 0.145 | | | 0.269 |
| 9Li -> 9Be<br>3/2- -> 3/2- | 0.044 | 0.244 | | 0.129 | | 0.276 | 0.275 |
| 9Li -> 9Be*<br>3/2- -> 5/2- | 0.119 | 0.232 | | 0.284 | | 0.338 | 0.336 |
| 9C -> 9B<br>3/2- -> 3/2- | 0.028 | 0.259 | | 0.124 | | 0.287 | 0.286 |
| 10C -> 10B<br>0+;1 -> 1+;0 | 2.062 | 1.942 | | 2.158 | | 1.862 | 1.854 |
| 11C -> 11B<br>3/2- -> 3/2- | 1.92 | 1.02 | | | | 1.18 | 1.17 |