Single-neutron strength in N=29 isotones: Subshell closures and missing $\nu g_{9/2}$ strength

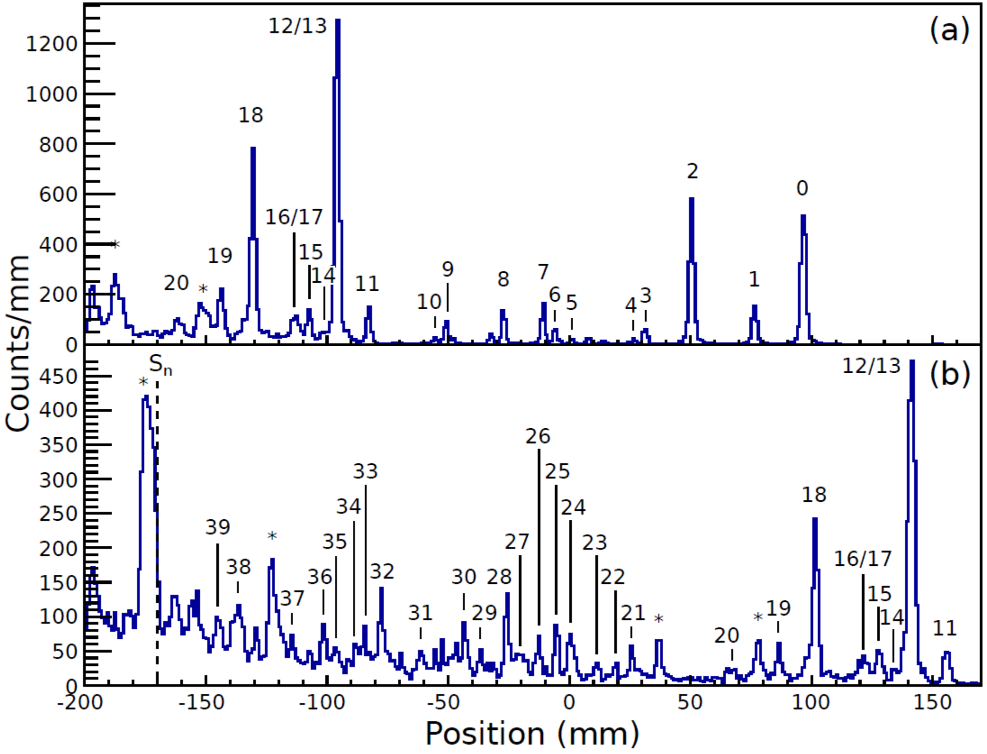
Paul Cottle

NSF Site Visit, John D. Fox Laboratory, Florida State University

N=29 isotones via the (*d,p*) reaction with the SE-SPS

Single neutron strength in N=29 isotones

^{54}Fe(d,p)^{55}Fe 16 MeV Lab angle = 30 deg



^{50}Ti(d,p)^{51}Ti REU w/Ursinus (2019)

^{54}Fe(d,p)^{55}Fe REU w/Ursinus (2021)

^{51}V(d,p)^{52}V I. Hay Senior Thesis (2022)

^{52}Cr(d,p)^{53}Cr REU w/Ursinus (2022)

N=29 isotones via the (*d*,*p*) reaction with the SE-SPS

Single neutron strength in N=29 isotones

PHYSICAL REVIEW C **103**, 064309 (2021)

^{50}Ti(d, p)^{51}Ti: Single-neutron energies in the N = 29 isotones, and the N = 32 subshell closure

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^{54}Fe(d, p)^{55}Fe and the evolution of single neutron energies in the N = 29 isotones

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$g_{9/2}$ neutron strength in the N = 29 isotones and the ^{52}Cr(d, p)^{53}Cr reaction

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PHYSICAL REVIEW C **109**, 024302 (2024)

Measurement of $g_{9/2}$ strength in the stretched 8^- state and other negative parity states via the ^{51}V(d, p)^{52}V reaction

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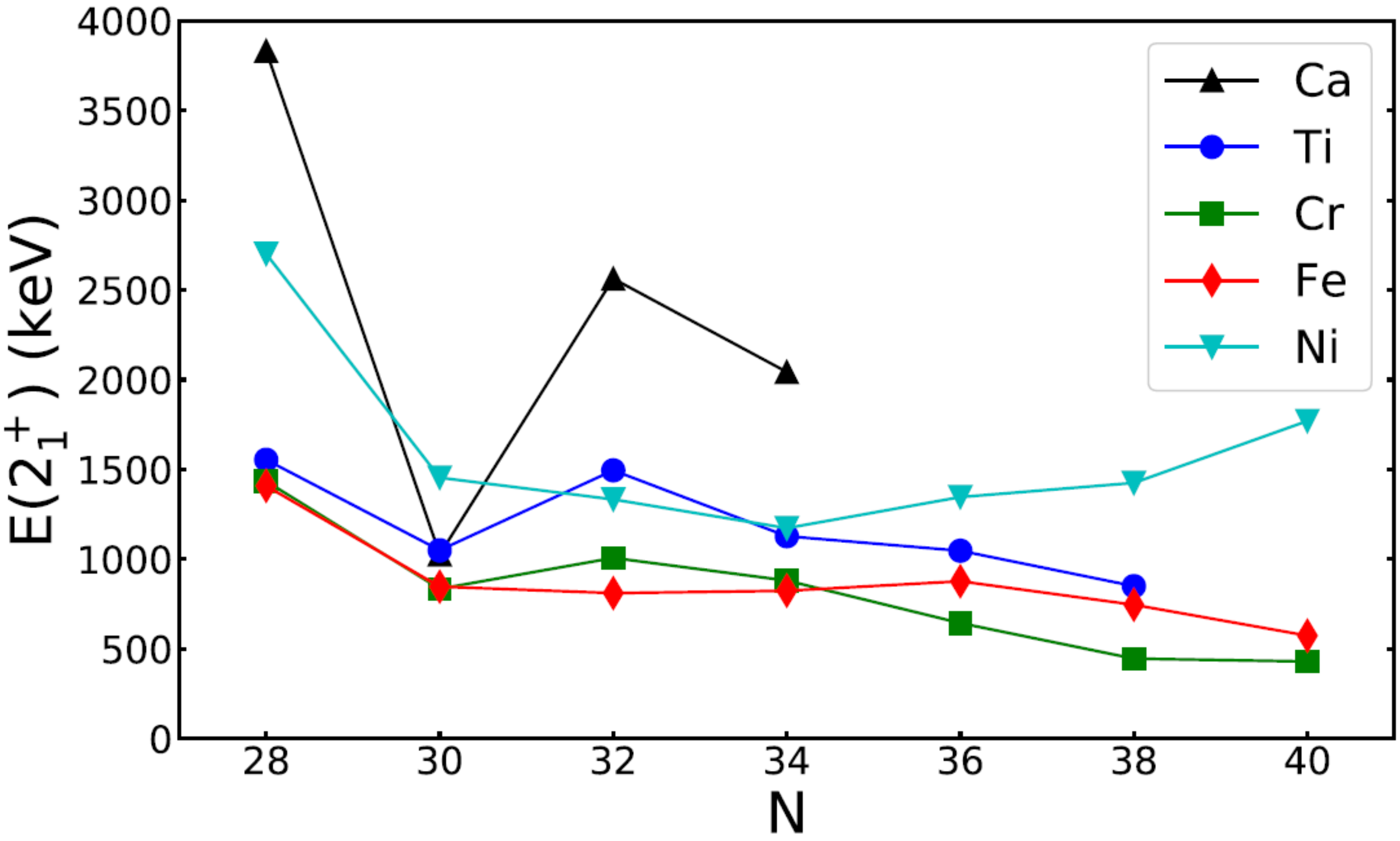
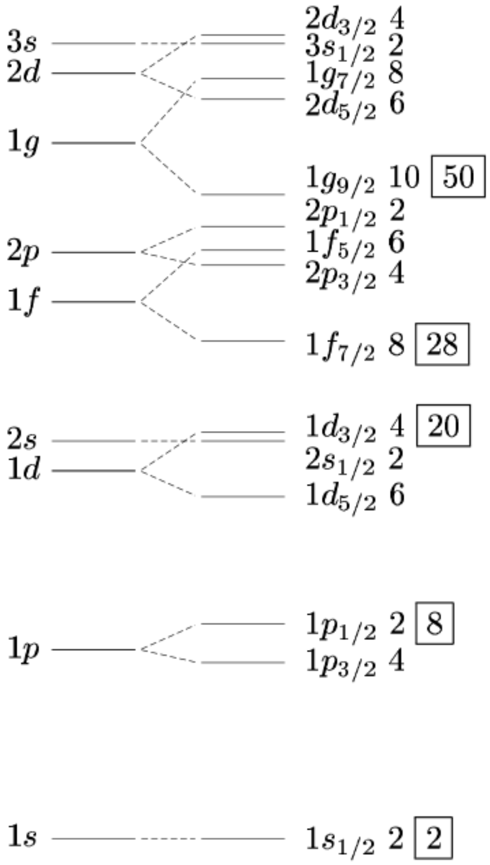
fp orbits and the *N*=32 subshell closure

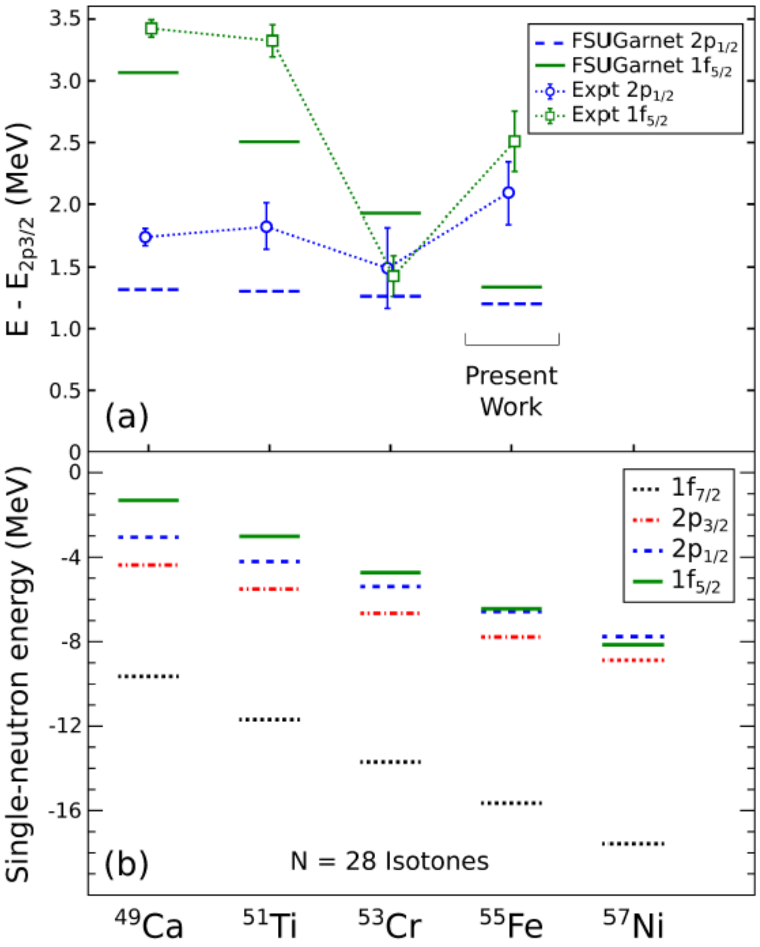


Single neutron strength in N=29 isotones

fp orbits and the *N*=32 subshell closure



fp orbits and the *N*=32 subshell closure



^{49}Ca: Y. Uozumi *et al.*, Nucl. Phys. A 576, 123 (1994).

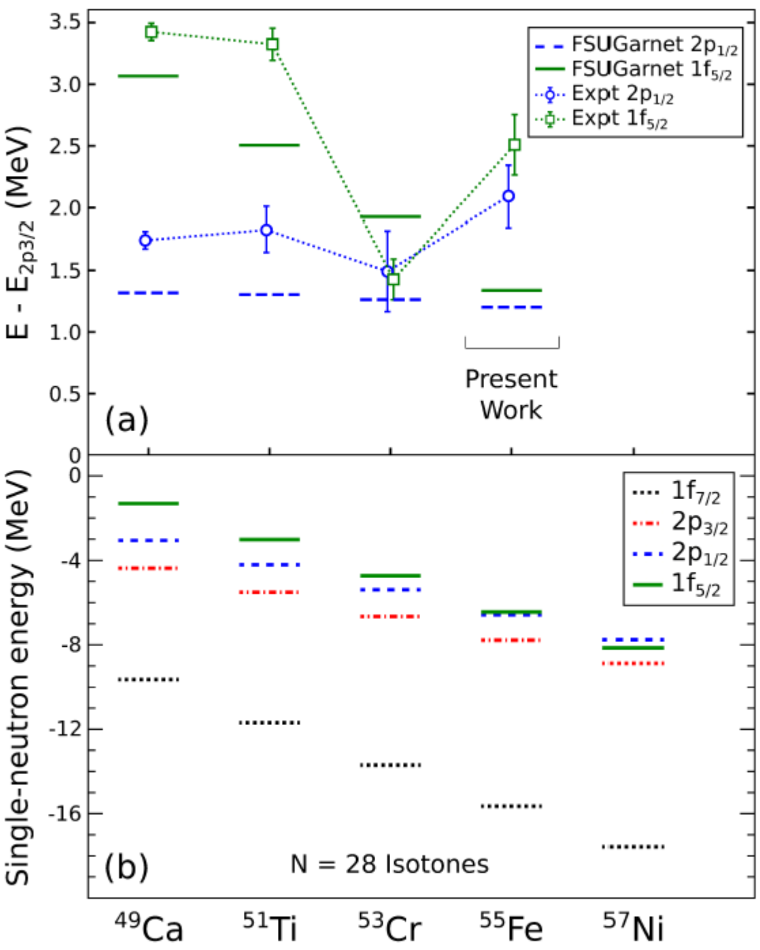
^{51}Ti: L.A. Riley *et al.*, Phys. Rev. C 103, 064309 (2021).

^{53}Cr: H. Junde, Nucl. Data Sheets 110, 2689 (2009).

^{55}Fe: L.A. Riley *et al.*, Phys. Rev. C 106, 064308 (2022).

Theory: J. Piekarewicz, Covariant Density Functional Theory calculations with the FSUGarnet covariant energy density functional

fp orbits and the *N*=32 subshell closure



Analysis of ^{52}Cr(*d,pγ*)^{53}Cr underway (L.A. Riley *et al.* at Ursinus College) to try to untangle $p_{3/2}$ from $p_{1/2}$ and $f_{5/2}$ from $f_{7/2}$ to improve *fp* single neutron energies.

fp orbits and the *N*=32 subshell closure

Use ^{49}Ti(*t*,*p*) reaction to distinguish between 5/2$^-$ and 7/2$^-$ states in ^{51}Ti

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THE INFLUENCE OF 2p-1h CONFIGURATIONS ON THE LOW-LYING STATES OF ^{51}Ti

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Received 24 July 1968

Experimental evidence for 2p-1h configurations in ^{51}Ti is obtained from study of the reaction ^{49}Ti(t, p)^{51}Ti. To account for the relative intensities of the (t,p) transitions such configurations need to be included in shell-model calculations.

As part of a programme linking (t,p) and (d,p) studies to the same final nucleus we have examined odd-*A* nuclei with one neutron beyond closed shells or sub-shells e.g. ^{27}Mg [1], ^{51}Ti, ^{59}Fe [2] and ^{89}Sr [3]. Two-nucleon transfer reactions like the (t,p) reaction may be expected to excite configurations other than those seen in the (d,p) reaction and hence provide a more exacting test of theoretical calculations.

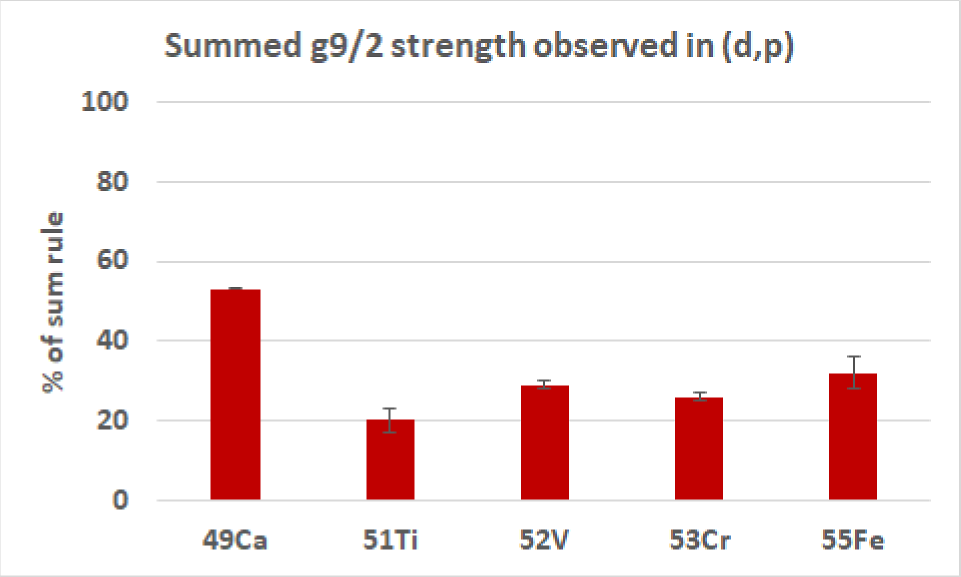
For *N* = 29 nuclei shell-model calculations [e.g.4] are based on configurations obtained by coupling the odd neutron in either the $2p_{\frac{3}{2}}$, $2p_{\frac{1}{2}}$ or $1f_{\frac{5}{2}}$ orbit to the even parity states of the proton core. A fair description of the level positions below ≈ 3 MeV excitation and of the spectroscopic factors observed in (d,p) reactions is then ob-

Table 1
^{51}Ti data from the ^{49}Ti(t,p) and ^{50}Ti(d,p) reactions.

			(t,p) Rel. Int.		
E_x	J^π	L	Expt	Theory	Expt S(d,p)
0	$\frac{3}{2}^-$	2	1.0	1.0	0.82
1.16	$\frac{1}{2}^-$	4	0.10	0.35	0.59
1.43	$\frac{7}{2}^-$	0	1.38	-	0.075
1.56	$\frac{5}{2}^-$	2	0.62	0.09	0.04
2.14	$\frac{5}{2}^-$	2	0.12	0.003	0.28
2.19	$\frac{3}{2}^-$	2	0.23	0.34	0.06
2.69	$\frac{7}{2}^-$	0	26.0	-	0.01
2.90	$\frac{1}{2}^-$	4	0.25	0.41	0.34

Single neutron strength in N=29 isotones

$\nu g_{9/2}$ strength observed in N=29 isotones



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^{52}V: I.C.S. Hay *et al.*, Phys. Rev. C 109, 024302 (2024).

^{53}Cr: L.A. Riley *et al.*, Phys. Rev. C 108, 044306 (2023).

^{55}Fe: L.A. Riley *et al.*, Phys. Rev. C 106, 064308 (2022).

$\nu g_{9/2}$ strength observed in N=29 isotones

Open questions:

1) Are we using the right sum rule?

Kay, Schiffer and Freeman [Phys. Rev. Lett. 111, 042502 (2013)]:

Spectroscopic strengths quenched by short-range correlations between nucleons, as in (*e,e'p*). Maximum spectroscopic strength is 55±10% of that expected from mean field theory.

John Millener (private communication during the last few weeks):

Calculations of $1\hbar\omega$ excitations introduce spurious states. Sum rule must correct for this.

Even with these caveats, we still may be missing $\nu g_{9/2}$ strength.

$\nu g_{9/2}$ strength observed in N=29 isotones

More open questions:

2) Is there a substantial amount of $\nu g_{9/2}$ strength above the particle thresholds?

Piekarewicz Covariant Density Functional Theory calculations say that $\nu g_{9/2}$ unbound in ^{48}Ca, ^{50}Ti and ^{52}Cr; bound by only 1.4 MeV in ^{54}Fe.

3) Are we missing a substantial amount of $\nu g_{9/2}$ strength distributed among many bound states?

$\nu g_{9/2}$ strength observed in N=29 isotones

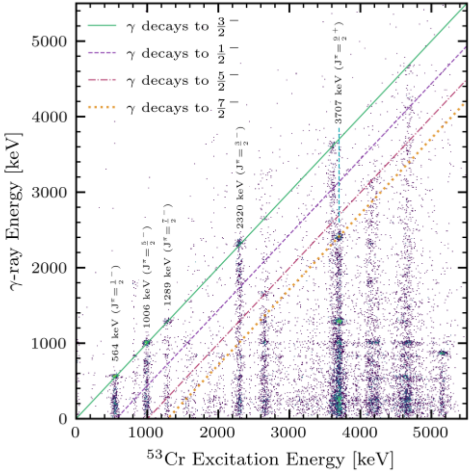
How to search for $\nu g_{9/2}$ strength with greater sensitivity

- Use the (α,^{3}He) reaction

  ^{51}V(α,^{3}He)^{52}V at 32 MeV: Incoming α and outgoing ^{3}He differ in L by 6.8ħ.

  ^{51}V(d,p)^{52}V at 16 MeV: Incoming d and outgoing p differ in L by 1.1ħ.

- Particle-γ coincidences with CeBrA.

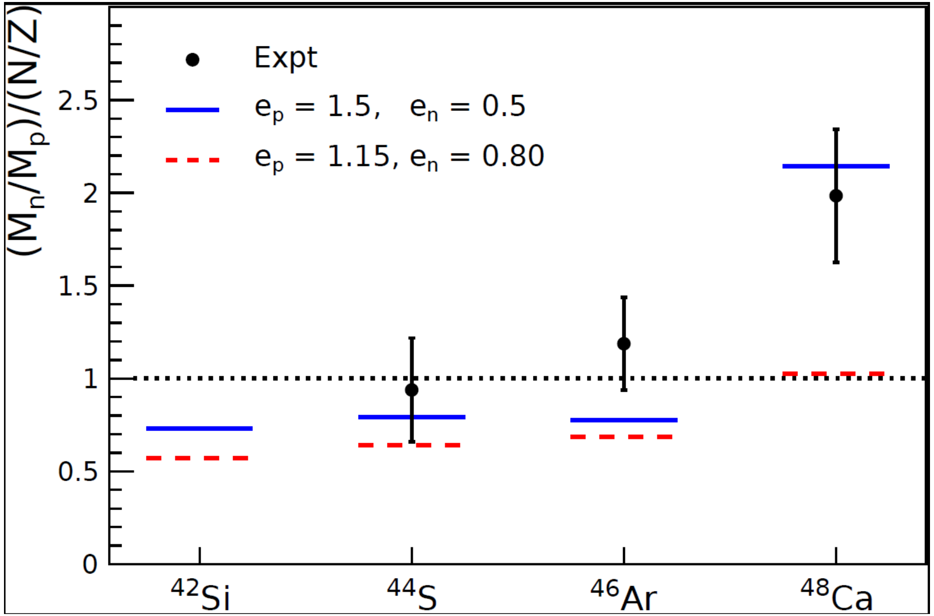


Going forward

- Work on pinning down J^{π} assignments using particle-γ coincidences and the ^{49}Ti(t,p)^{51}Ti reaction to reduce uncertainties in single neutron energies.

- Hunt for missing $\nu g_{9/2}$ strength using (α,^{3}He) reactions and particle-γ coincidences.

Postscript: M_n/M_p in ^{42}Si via Coulex and (*p,p'*) – FRIB expt 21001



Ursinus/FSU/MSU collaboration (PDC co-spokesperson)

Coulex measurement completed summer 2023 (being analyzed).

(*p,p'*) scheduled for late March 2024.

L.A. Riley *et al.*, Phys. Rev. C 100, 044312 (2019).

Single neutron strength in N=29 isotones