

# Influence of the N-N tensor force on the magicity of the $^{54}\text{Ca}$ nucleus

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# Outline of talk

- 1. Experimental facts in the Ca chain
- 2. The Skyrme EDF for ground and excited states
- 3. Single-particle spectra and subshell closures
- 4. Low-lying  $2+$  states
- 5. Conclusion

E. Yüksel, NVG, E. Khan, K. Bozkurt,  
Phys. Rev. C 89, 064322 (2014)

# LETTER

doi:10.1038/nature12522

## Evidence for a new nuclear ‘magic number’ from the level structure of $^{54}\text{Ca}$

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Nature 502, 207 (2013)

- Data from proton knock out reactions
- First  $2+$  state in  $^{54}\text{Ca}$  found at about 2 MeV: indication that  $2p_{1/2}$  (neutron) is partly occupied while  $1f_{5/2}$  (neutron) is partly empty.

How much « partly »?

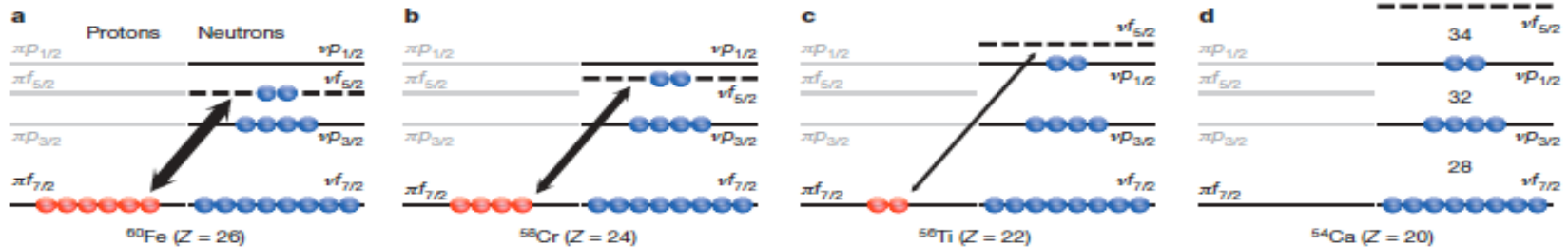
We show the importance of the effective tensor interaction in answering this question

# The N=34 isotones

## « Otsuka's effect »:

Figure from Steppenbeck et al.

RESEARCH LETTER



The interaction induced by a tensor force between a proton in a  $(l, j=l+1/2)$  state and a neutron in a  $(l, j=l-1/2)$  state is attractive

T.Otsuka, T.Suzuki, R. Fujimoto, H.Grawe, Y.Akaishi,  
Phys. Rev. Lett. 95, 232502 (2005)

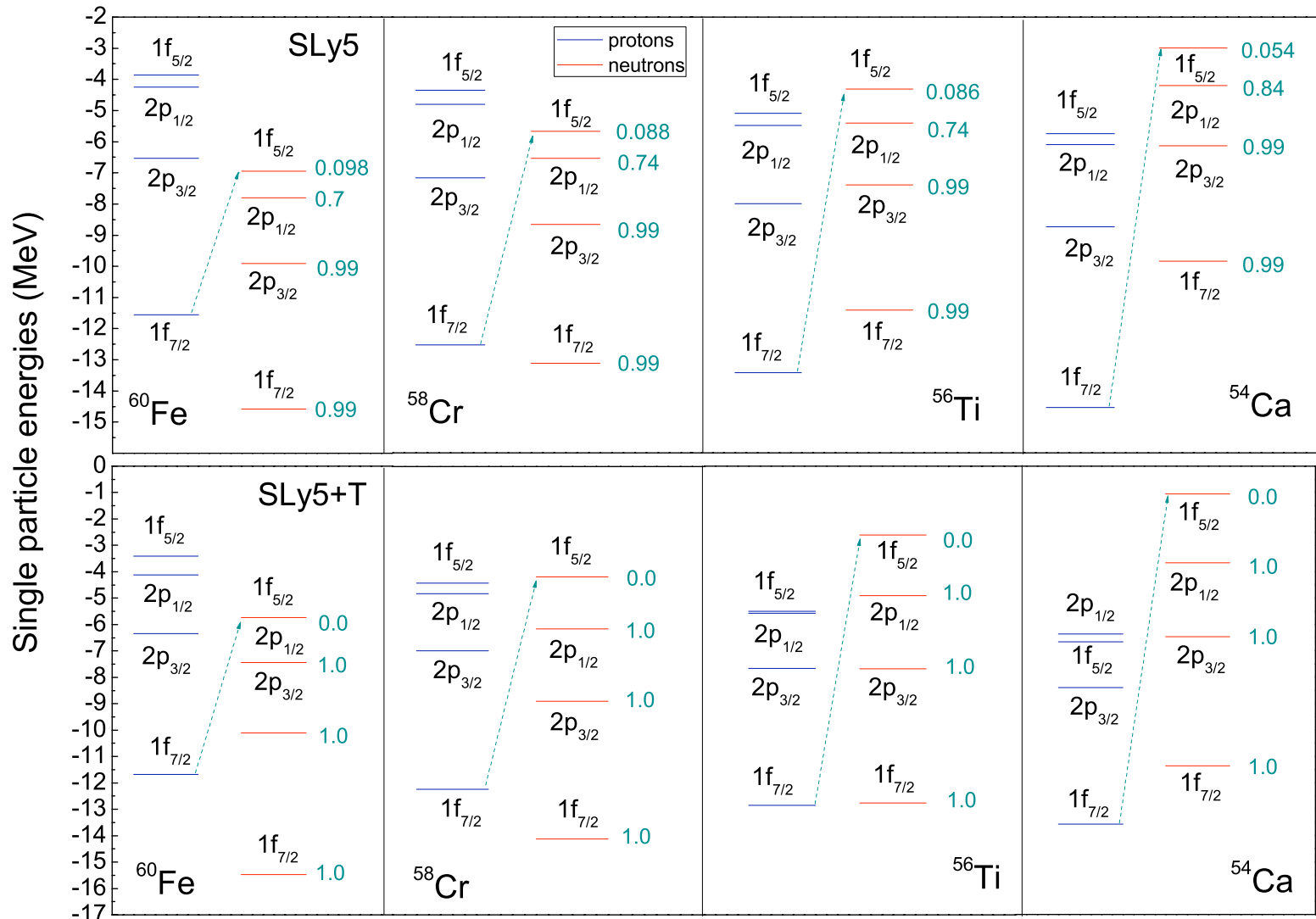
# Theoretical predictions of single-particle spectra

- **Model:** Hartree-Fock-Bogoliubov mean field
- **Inputs:** Skyrme-type Energy-Density Functionals
- **Focus:** effects of the tensor component of the EDF on the quasi-particle energies and occupation numbers

# Models used

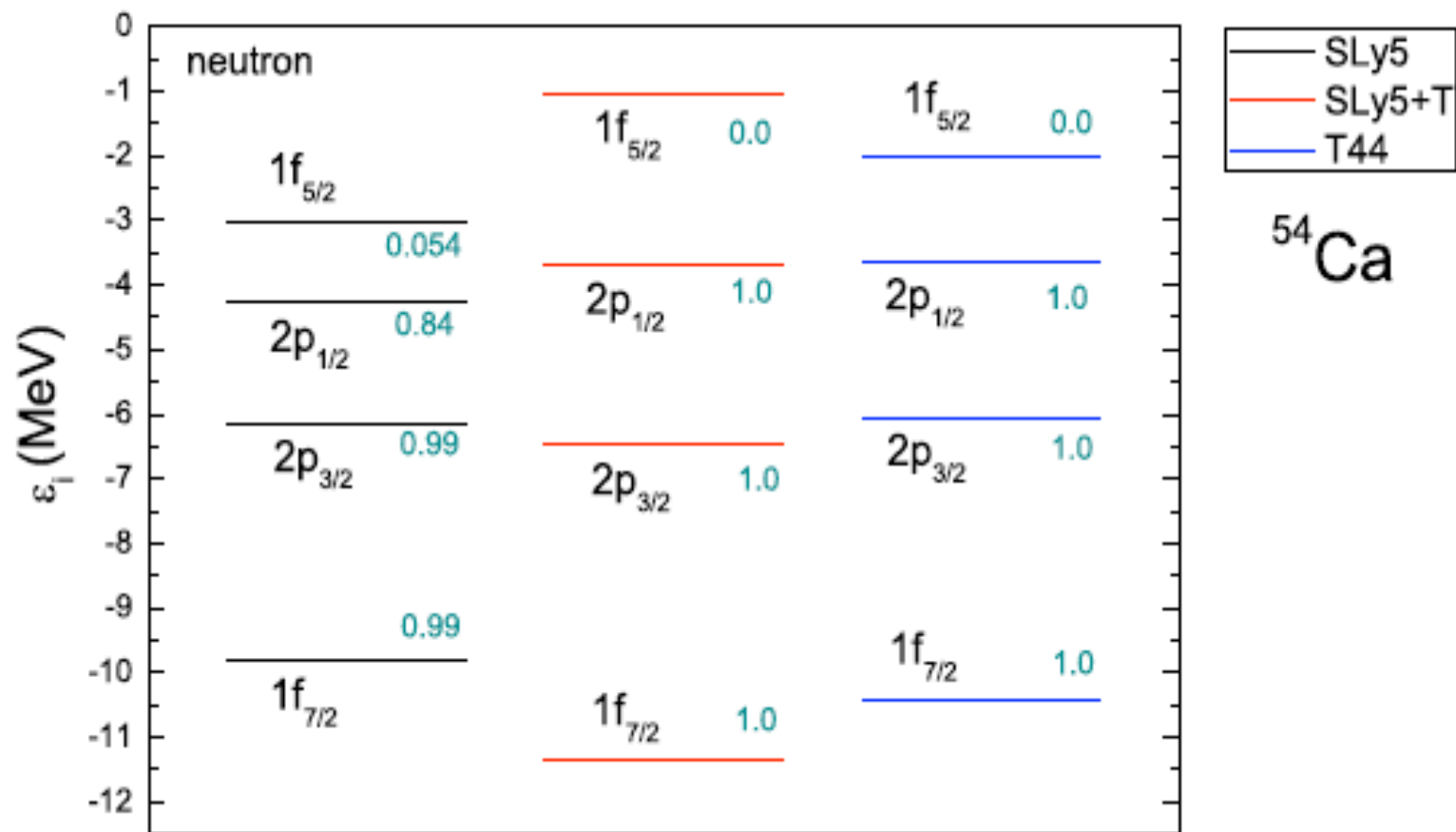
- Recent work:
- M. Grasso, Phys. Rev. C 89, 034316 (2014)
- found magicity for  $^{52,54}\text{Ca}$  if described by Skyrme Hartree-Fock, using SLy5+Tensor
  
- This work:
- Skyrme Hartree-Fock-Bogoliubov for ground states
- QRPA for excited states
- SLy5, SLY5+T, T44 for interactions:
- SLY5+T: G.Colò et al, Phys.Lett.B 646,227(2007)
- T44: T.Lesinski et al, Phys. Rev. C 76, 014312 (2007)
- Contact, density-dependent pairing force adjusted on  $2n$  separation energies and  $2+$  energies of  $42-46\text{Ca}$  chain.

# Effects of tensor force on s.p. spectra and occupation probabilities in N=34 isotones





# Effect of tensor force on 2p<sub>1/2</sub> closure in <sup>54</sup>Ca

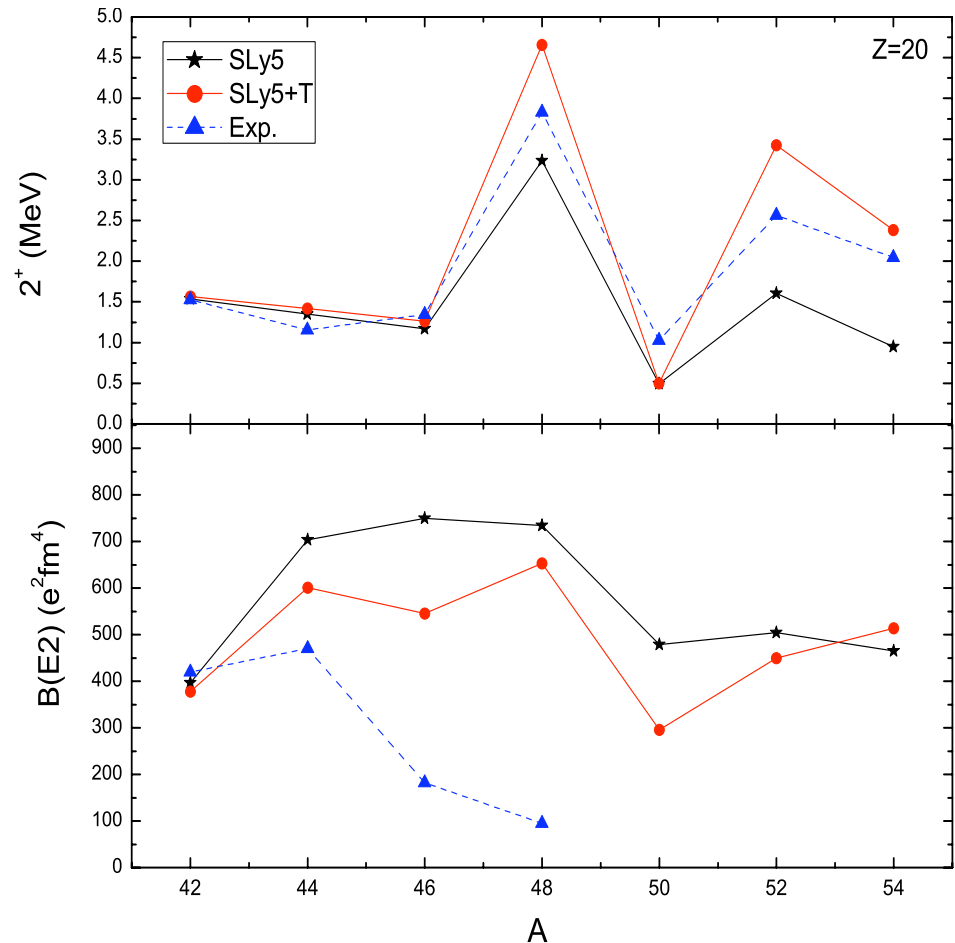


Model: HFB with Skyrme-type EDF

# First 2+ energies and B(E2) values

Exp.:

- S. Raman et al, At. Data & Nucl. Data Tables 78, 1128 (2001)
- D. Steppenbeck et al, Nature 502, 207 (2013)

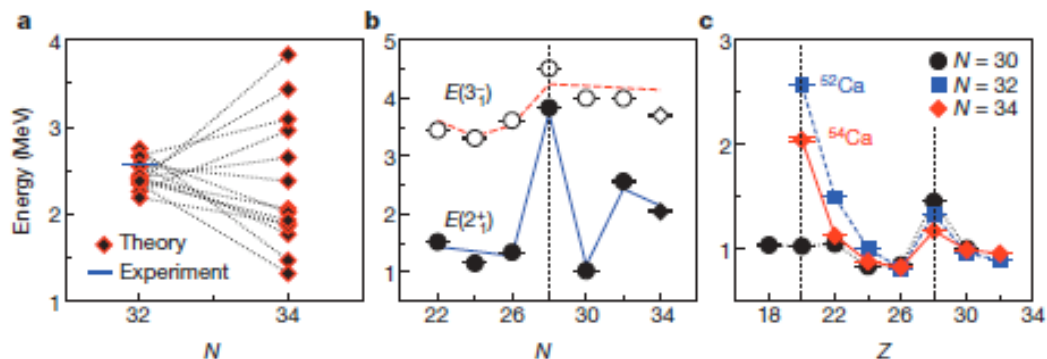


- General remarks about the low)lying  $J=2+$  predictions:
- $2+$  energies reasonably well described. The tensor interaction helps.
- Measured  $B(E2)$  values very small in  $46,48\text{Ca}$ . The tensor interaction does not lead to such small values. Difficult to explain within QRPA.
- No experimental information on  $B(E2)$  in  $50,52,54\text{Ca}$ .

# Summary

- -The 4  $N=34$  isotones:  $^{60}\text{Fe}$ ,  $^{58}\text{Cr}$ ,  $^{56}\text{Ti}$ ,  $^{54}\text{Ca}$  are explored in a HFB-QRPA model
- **The tensor component** of the interaction determines the magic character of  $^{54}\text{Ca}$  (larger  $2p_{1/2}$ - $1f_{5/2}$  neutron gap, occupation numbers 1 and 0)
- It also brings the energy of the **first  $2+$  state** in  $^{54}\text{Ca}$  close to the measured value.

**THANK YOU !**



**Figure 2 | Systematics of excited-state energies in even-even Ca isotopes and neighbouring nuclei.** **a**, Theoretical predictions of the energy of the first  $2^+$  state for  $^{52}\text{Ca}$  ( $N = 32$ ) and  $^{54}\text{Ca}$  ( $N = 34$ ) (refs 14–16, 19–24). The solid blue line represents the experimental result for  $^{52}\text{Ca}$  (refs 6, 7). **b**, Energies of the first  $2^+$  (filled symbols) and  $3^-$  (open symbols) levels for even-even  $^{42-54}\text{Ca}$

isotopes. The results of the present study are indicated by diamonds at  $N = 34$ . The solid and dashed lines are shell-model predictions of the first  $2^+$  and  $3^-$  energies, respectively (see text for details). **c**,  $E(2_1^+)$  along the  $N = 30, 32$  and  $34$  isotonic chains. The solid and dashed lines are intended to guide the eye. Vertical dotted lines represent the standard magic numbers.