Influence of the N-N tensor force on the magicity of the 54Ca 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}Ca

D. Steppenbeck[1], S. Takeuchi[2], N. Aoi[3], P. Doornenbal[2], M. Matsushita[1], H. Wang[2], H. Baba[2], N. Fukuda[2], S. Go[1], M. Honma[4], J. Lee[2], K. Matsui[5], S. Michimasa[1], T. Motobayashi[2], D. Nishimura[6], T. Otsuka[1,5], H. Sakurai[2,5], Y. Shiga[7], P.-A. Söderström[2], T. Sumikama[8], H. Suzuki[2], R. Taniuchi[5], Y. Utsuno[9], J. J. Valiente-Dobón[10] & K. Yoneda[2]

Nature 502, 207 (2013)

- Data from proton knock out reactions
- First 2+ state in 54Ca found at about 2 MeV: indication that 2p1/2 (neutron) is partly occupied while 1f5/2 (neutron) is partly empty.

How much « partly »?

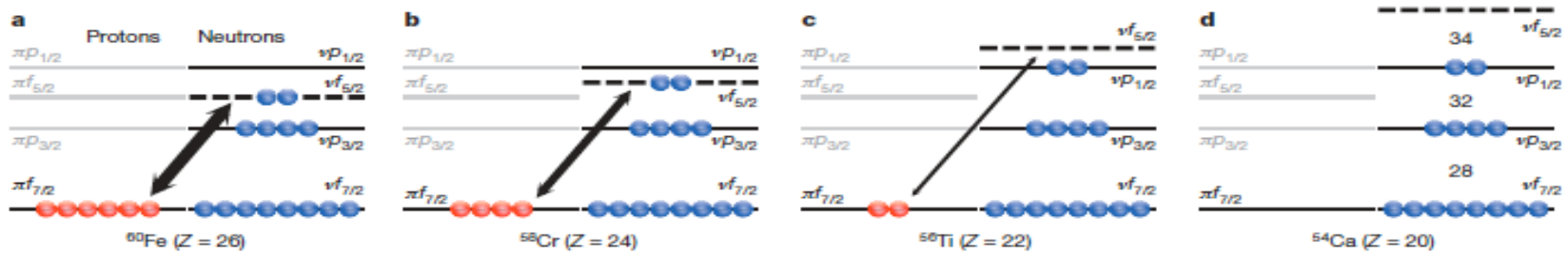
We show the importance of the effective tensor interaction in answering this question

The N=34 isotones

« Otsuka's effect »:

RESEARCH LETTER

Figure from Steppenbeck et al.



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

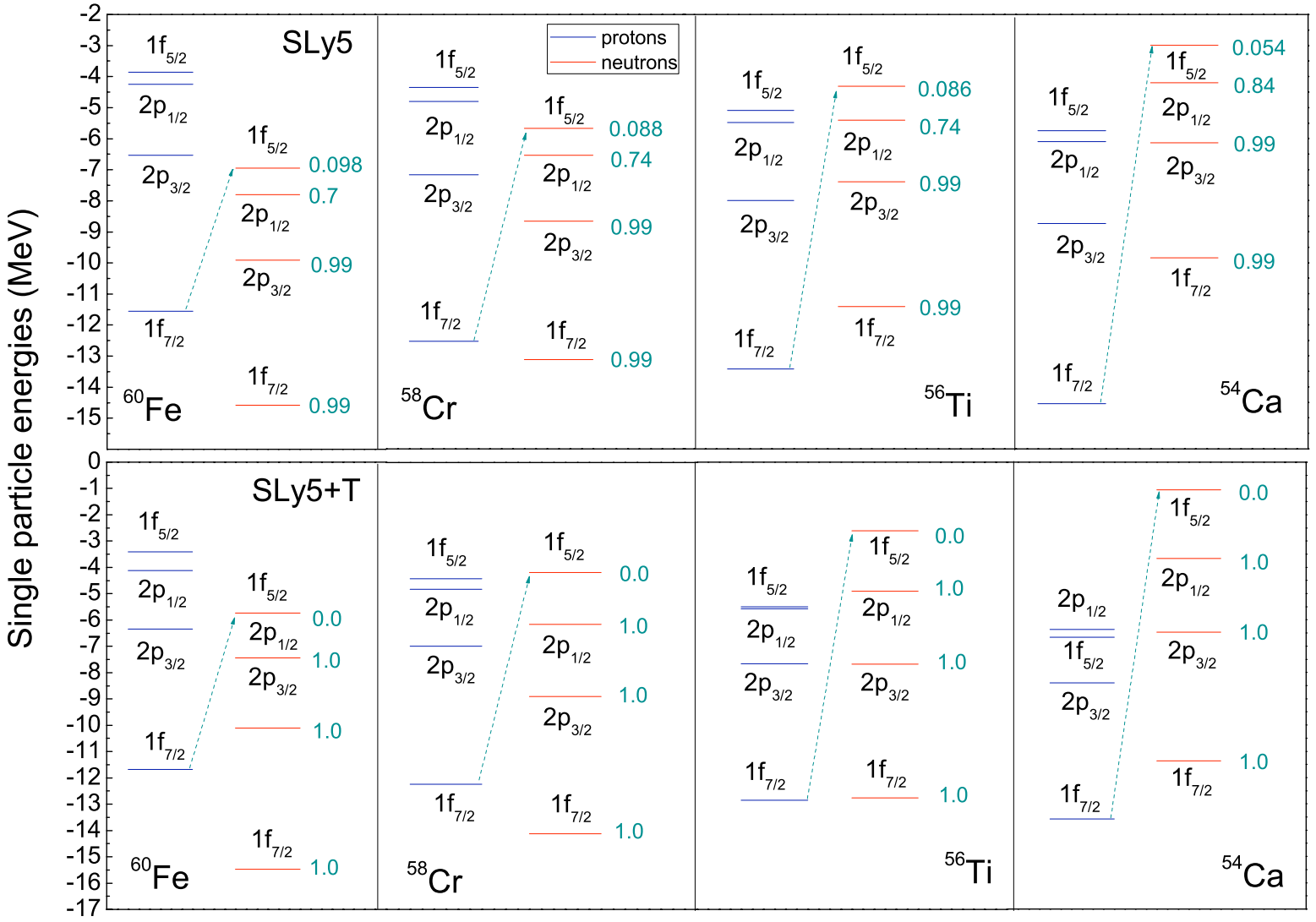
- Model: Hartree-Fock-Bogoliubov mean field
- Inputs: Skyrme-type Energy-Density Functionals
- Focus: effects of the tensor component of the EDF on the quasi-particle energies and occupation numbers

Models used

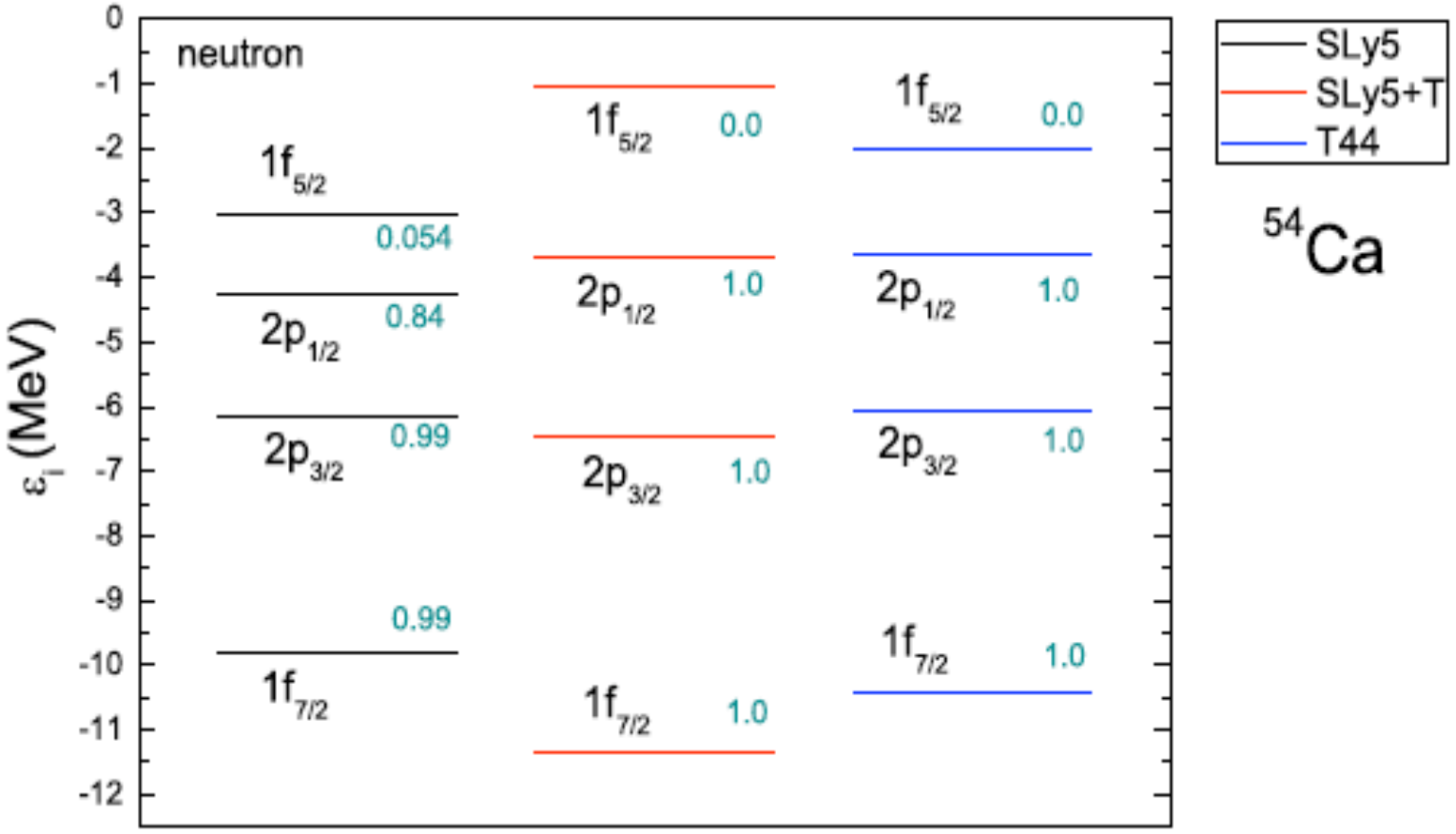
- Recent work:
- M. Grasso, Phys. Rev. C 89, 034316 (2014)
- found magicity for 52,54Ca if described by Skyrme Hartree-Fock, using SLy5+Tensor

- 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 42-46Ca chain.

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



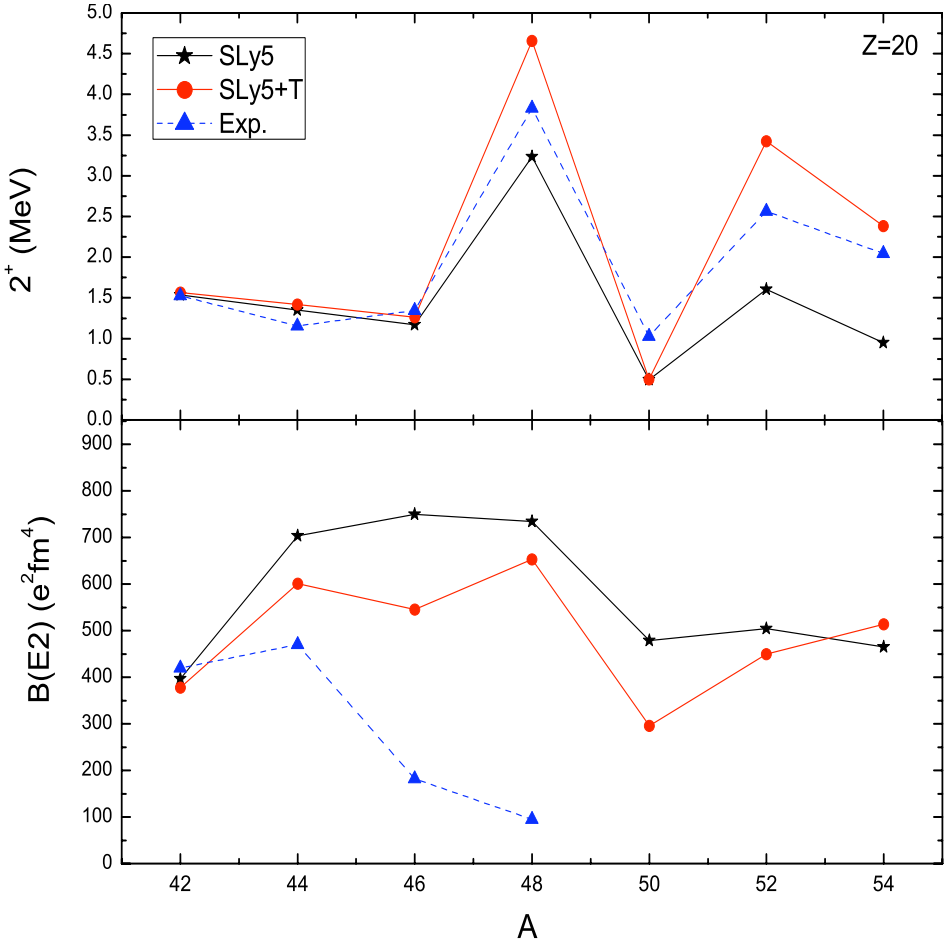
Effect of tensor force on 2p1/2 closure in 54Ca



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 46,48Ca. The tensor interaction does not lead to such small values. Difficult to explain within QRPA.

- No experimental information on B(E2) in 50,52,54Ca.

Summary

- -The 4 N=34 isotones: 60Fe, 58Cr, 56Ti, 54Ca are explored in a HFB-QRPA model
- The tensor component of the interaction determines the magic character of 54Ca (larger 2p1/2-1f5/2 neutron gap, occupation numbers 1 and 0)
- It also brings the energy of the first 2+ state in 54Ca close to the measured value.

THANK YOU !

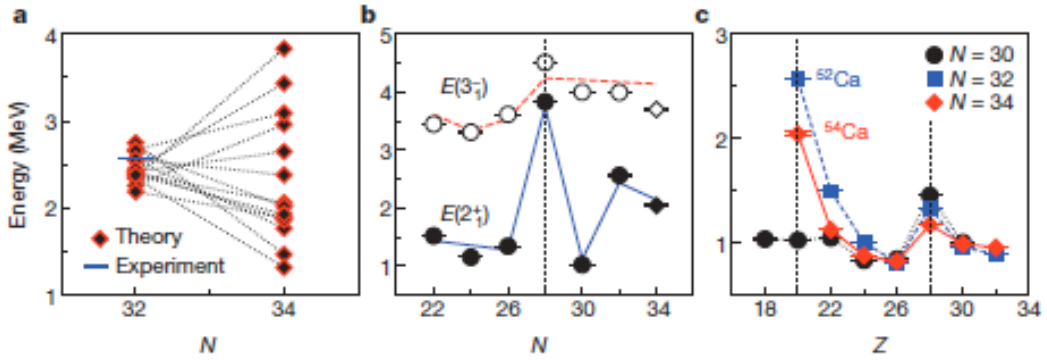


Figure 2 | Systematics of excited-state energies in even–even Ca isotopes and neighbouring nuclei. **a**, Theoretical predictions of the energy of the first 2^+ state for ^{52}Ca ($N = 32$) and ^{54}Ca ($N = 34$) (refs 14–16, 19–24). The solid blue line represents the experimental result for ^{52}Ca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