Direct reactions with SPES beams: Nuclear magicity at Z∼50 and N∼82 n-capture cross section via surrogate method

G. de Angelis, D. Mengoni, N.Erduran

INFN - LNL, Legnaro Italy
INFN - Sezione and University, Padova - Italy
Sabahattin Zaim University, Istanbul - Turkey

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Outline

Collaboration

G. de Angelis[1], M. Gelain[1], F.Gramegna[1], T. Marchi[1], V. Modamio[1], D.R. Napoli[1], G. Prete[1], J.J. Valiente-Dobón[1], D. Mengoni[2], D. Bazzacco[2], A. Boso[2], S. Lunardi[2], S. Lenzi[2], R. Menegazzo[2], F. Recchia[2], M. N. Erduran[3], S. Erturk[4],A. Kusoglu[5], M. Yalcinkaya[5] A. Gargano[6],G. La Rana[6], A. Nannini[7], B. Melon[7], G. Casini[7], C.Michelagnoli[8], D. Verney[9], M. Assié[9], F. Azaiez[9], D. Beaumel[9], Y. Blumenfeld[9], M.-C. Delattre[9], S. Franchoo[9], F. Ibrahim[9], A. Gottardo[9], R. Li[9], I. Matea[9], P. Morfouace[9], I. Stefan[9], D. Suzuki[9], D.T Yordanov[9], A. Gadea[10], D. Tonev[11], P. Petkov[11], B. Blank[12], J. Praena[13], S. Pain[14], M. Smith[14], K. Chipps[14],K. Jones[15], A. Ratkiewicz [16],T. Baugher [16], J. Cizewski [16], R. Kozub[17], D. Bardayan[18], J.F. Smith[19], M.Scheck[19], R. Chapman[19]

[1]*INFN, Laboratori Nazionali di Legnaro, Legnaro, Italy.* [2]*Dipartimento di Fisica e Astronomia and INFN, Sezione di Padova, Padova, Italy.* [3]*Istanbul Sabahattin Zaim University, Turkey.* [4] *Nigde University, Turkey.* [5] *Istanbul University, Turkey.* [6]*Dipartimento di Fisica and INFN, Sezione di Napoli, Padova, Italy.* [7]*Dipartimento di Fisica and INFN, Sezione di Firenze, Padova, Italy.* [8]*GANIL, Caen, France.* [9]*IPN Orsay, IN2P3/CNRS-University of Paris Sud (France).* [10]*Instituto de Fisica Corpuscular, Valencia, Spain.* [11]*Institut for Nuclear Research and Nuclear Energy, BAS, Sofia, Bulgaria.* [12]*CENBG, Bordeaux, France.* [13]*CNA, Sevilla, Spain.* [14]*ORNL, USA.* [15]*University of Tennessee, USA.* [16]*Rutgers University, USA.* [17]*Tennessee Technological, USA.* [18]*University of Notre Dame, USA.* [19]*UWS in Paisley, PA1 2BE Paisley, Scotland, UK.*

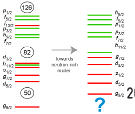
Nuclear Physics

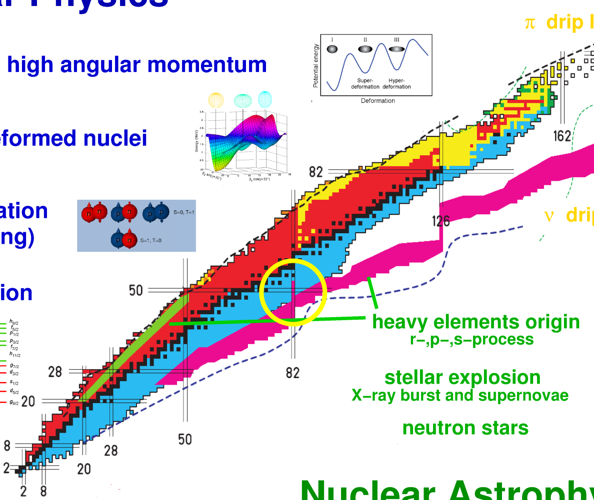
high angular momentum

deformed nuclei

correlation (pairing)

shell evolution





heavy elements origin
r–,p–,s–process

stellar explosion
X–ray burst and supernovae

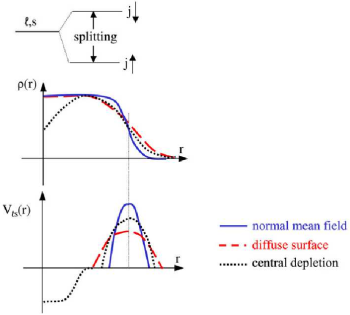
neutron stars

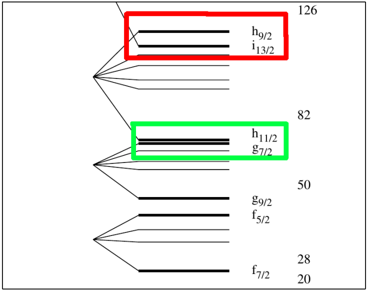
Nuclear Astrophysics

Around doubly-magic ^{132}Sn

SO term in exotic matter

- SO-interaction scales with the derivative of the nucleon densities

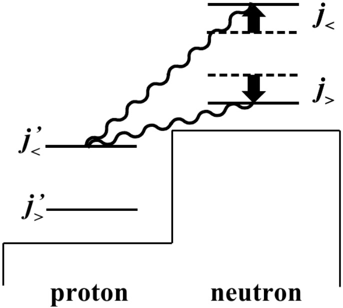


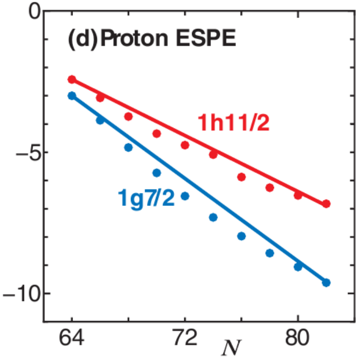


Shift of the proton single-particle energies

monopole part of the nuclear force

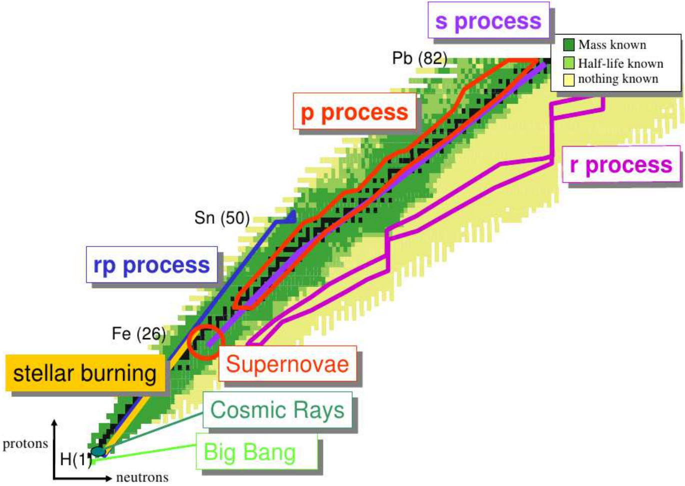
Attractive when spins of nucleons are antiparallel to their orbital angular momenta





Nucleosynthesis processes

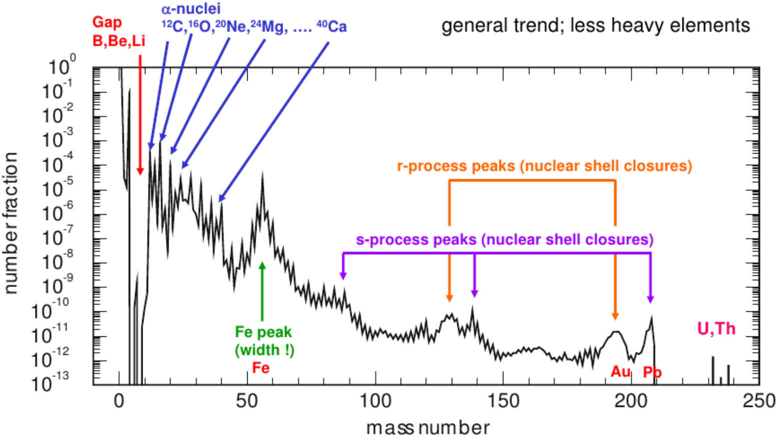
Implications on nuclear astrophysics



- Burbidge, Burbidge, Fowler, Hoyle, Rev. Mod. Phys. 29 (1957) 547

Solar abundances

Implications on nuclear astrophysics



determined from solar and stellar spectra and from meteorites

- N. Grevesse and A.J. Sauval, Space Science Reviews 85 (1998) 161

Nuclei around doubly closed shells: why?

In the independent particle SM the properties of a odd nucleus are determined by the odd unpaired nucleon.
This is expecially true for magic numbers that corresponds to significant gap in SPE.

Test of the model and its prediction capacity:

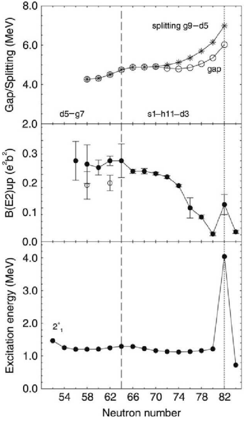
- SPE
- TBME

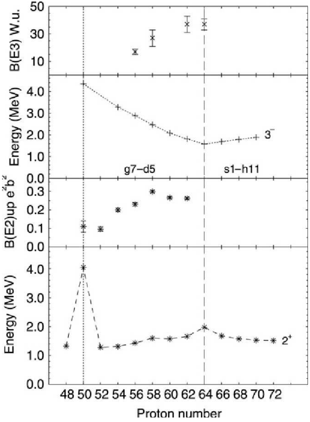
Around 132Sn

- Doubly-magic nucleus (with extreme N/Z)
- Proximity of the r-process path
- Proximity of the continuum states
- Three-body forces, appearence of new (sub-)shells

Experimental background

- SF, β decay, Coulomb excitation ... and transfer

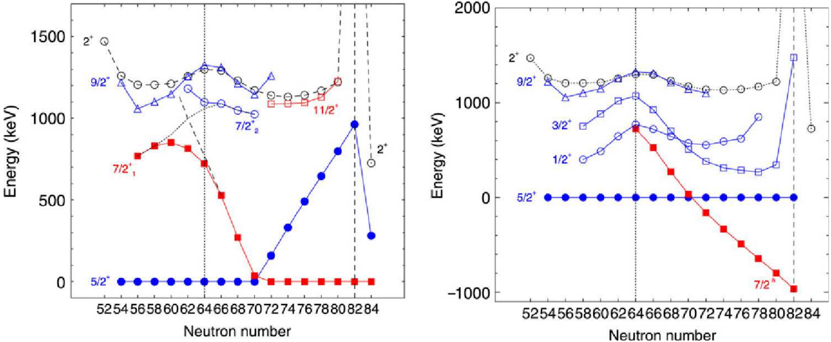




- ^{132}Sn behaves like a doubly-magic nucleus(E2+,BE2,S2N,gap,etc.)
- O.Sorlin et al., Prog.Part.Nucl.Phys. 61 (2008) 602 and reference therein
- RIKEN EURICA β-decay campaign

Z=51 proton orbits

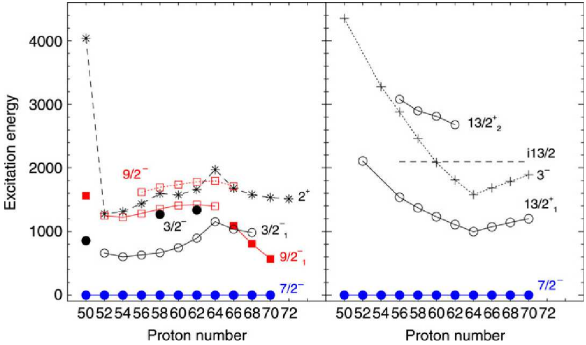
1. core coupling (2^+,3^-) : $9/2^+$, $11/2^+$, $3/2^+$, $1/2^+$
2. mixing between different configurations: $7/2^+$
3. single-particle states: $7/2^+$, $11/2^+$?



O.Sorlin et al., Prog.Part.Nucl.Phys. 61 (2008) 602 and reference therein

N=83 neutron orbits

1. core coupling (2^+,3^-) with neutron $f_{7/2}$
2. neutron single particle states
3. mixing

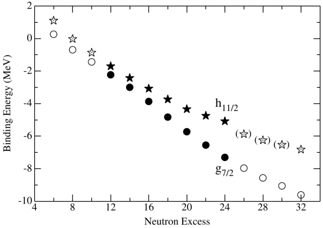


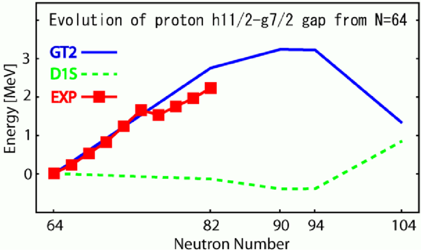
- O.Sorlin et al., Prog.Part.Nucl.Phys. 61 (2008) 602 and reference therein

Transfer beyond Z=50

^{A}Sn(^{4}He,t)$^{A+1}$Sb)

- Spectroscopic factors deduced for *l*=4,5 using DWBA model
- 7/2 and 11/2 states show a single-particle character
- Tensor part of interaction is fundamental to reproduce the exp trend



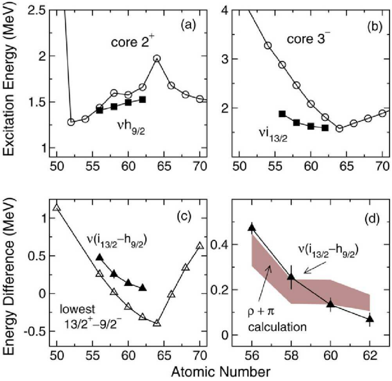


- J.P.Schiffer et al., Phys.Rev.Let.92, (2004) 162501
- T.Otsuka et al., Nucl.Phys. A 805 (2008) 127c

Transfer beyond N=82

$^{A}X(^{4}He,^{3}He)^{A+1}X)$ for ^{138}Ba, ^{140}Ce, ^{142}Nd, ^{144}Sm

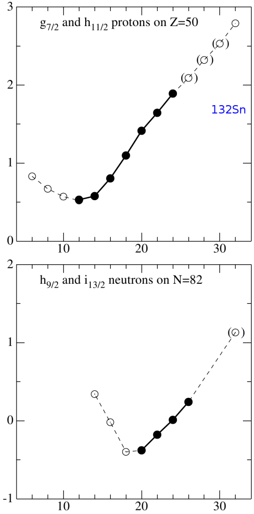
- Spectroscopic factors deduced for *l*=5,6 using DWBA model
- Energy difference fairly similar, no swap visible in the experiment
- Agreement LSSM calculations, discrepancies with MF.



- B.P.Kay et al., Phys.Lett.B658(2008) 216
- T.Otsuka et al., Phys.Rev.Lett.95 (2005) 232502

SO evolution with neutron excess

Interpretation



- density (rms and diffuseness) are most similar
- proton and neutron Fermi surface are equal

- J.P.Schiffer et al., Phys.Rev.Let.92, (2004) 162501

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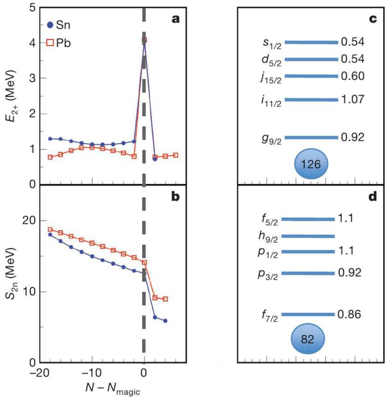
LETTERS

The magic nature of ^{132}Sn explored through the single-particle states of ^{133}Sn

K. L. Jones[1,2], A. S. Adekola[3], D. W. Bardayan[4], J. C. Blackmon[4], K. Y. Chae[1], K. A. Chipps[5], J. A. Cizewski[2], L. Erikson[5], C. Harlin[6], R. Hatarik[2], R. Kapler[1], R. L. Kozub[7], J. F. Liang[4], R. Livesay[5], Z. Ma[1], B. H. Moazen[1], C. D. Nesaraja[4], F. M. Nunes[8], S. D. Pain[2], N. P. Patterson[6], D. Shapira[4], J. F. Shriner Jr[7], M. S. Smith[4], T. P. Swan[2,6] & J. S. Thomas[6]

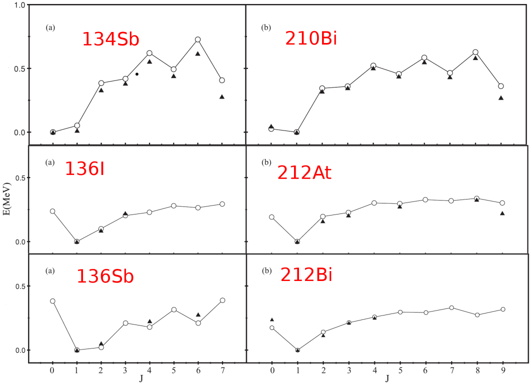


- single particle strength (S) concentrated in one state
- large discontinuites in numerous observables

LSSM calculations

Theoretical predictions outside N=82, compared with N=126

- Few valence particle nuclei above the doubly-closed magic 132Sn core
- realistic interacion
- good results for isotopes of Sn, Sb, Te, I, Xe, Cs with different interactions for $134 \lesssim A \lesssim 138$ and $50 \lesssim Z \lesssim 56$



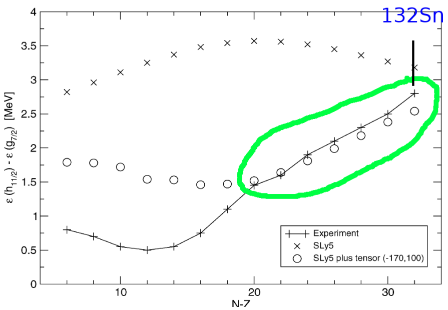
- L.Coraggio et al., Phys.Rev.C(R) 80 (2009) 021305

HFB calculations

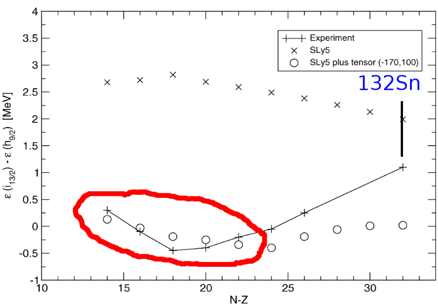
Theoretical predictions outside Z=50 and N=82

- tensor term in the effective Skyrme interaction

Protons on Z=50 core



Neutrons on N=82 core



- G.Colò et al.,Phys.Lett.B646 (2007) 227

What we can probe? and how?

- n states: (d,p) for neutron pickup, (d,t) for neutron stripping
- p states: (^{3}He,d) for proton pickup, (t,α) or (d,^{3}He) for proton pickup
- pairing: (t,p) or (p,t) for n-n pairing
- pairing: (p,^{3}He) or (d,α) for n-p pairing

target

- CH_2/CD_2 loaded carbon
- cryogenic gaseous
- jet

Proposed reactions at SPES

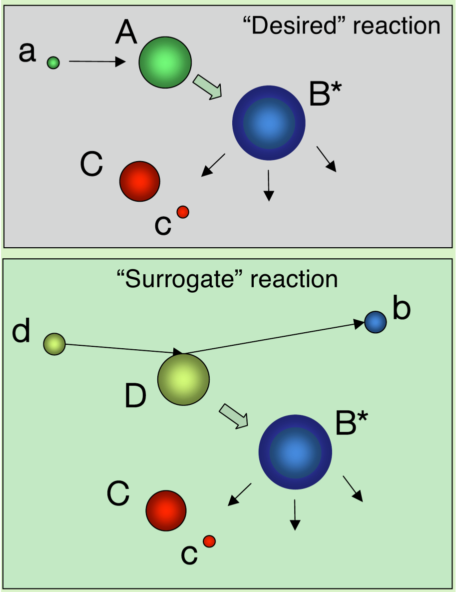
Expected SPES-beam intensity: $10^{5\div8}$ pps (10^5 required on target for transfer reactions at ISOLDE)

Systematic measurements in the region

- **(d,p)** : ^{133}Sn, ^{134}Sn, ^{133}Sb, ^{131}In
- **(d,t)** : ^{131}Sn, ^{134}Sn, ^{131}In
- **(d,^{3}He)** : ^{131}Sn, ^{133}Sn, ^{131}In

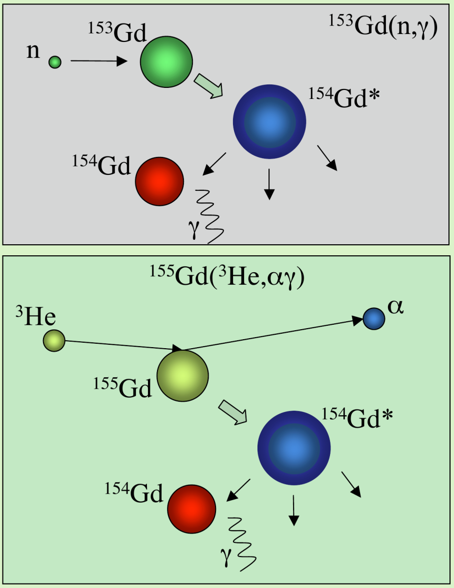
complemented by Coulomb excitation measurements?

Indirect Determination of Cross Sections



The Surrogate Nuclear Reactions approach is an indirect method for determining XS of CN reactions difficult to measure directly.

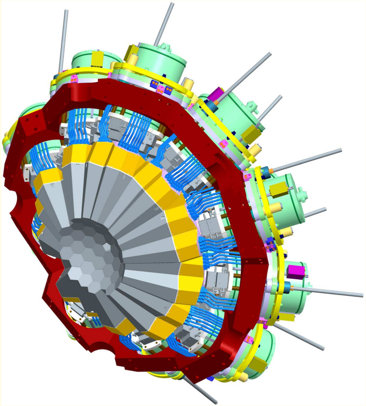
(n,γ) cross section



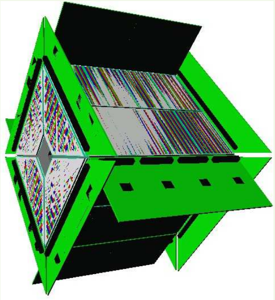
Various direct-reaction mechanisms can be employed to create the compound nucleus of interest.

Detector Setup

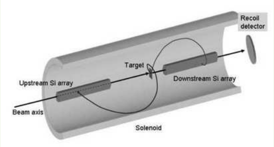
AGATA,GALILEO



TRACE, SPIDER



Solenoid



Summary and conclusions

- SPES RIB:
  10^{5-8} pps
- N∼82, Z∼51:
  Spectroscopic factor in Sb,Sn,In
- Detection Setup:
  AGATA, TRACE, SOLE, (SPIDER, DANTE)