Structure of Sb nuclei around ^{132}Sn as a testing ground for realistic shell model interactions

Bartłomiej Szpak
Institute of Nuclear Physics, Polish Academy of Sciences, Kraków, Poland

B. Fornal, B. Szpak, N. Cieplicka, W. Królas, K.H. Maier, M. Matejska-Minda
Institute of Nuclear Physics, Polish Academy of Sciences, PL-31342 Krakow, Poland

J. Dudek
IPHC, Département de Recherches Subatomiques IN2P3-CNRS and Université de Strasbourg, F-67037 Strasbourg, France

S. Lunardi, D. Bazzacco, E. Farnea, A. Gottardo, S. Lenzi, R. Menegazzo, D. Mengoni, C. Michelagnoli, F. Recchia, C.A. Ur
Department of Physics, University of Padova and INFN, Padova, Italy

G. de Angelis, D.R. Napoli, E. Sahin, J. Valiente-Dobon,
INFN, Laboratori Nazionali di Legnaro, Legnaro, Italy

G. de France, E. Clement
GANIL, Caen, France

D. Mengoni, J.F. Smith, R. Chapman, A. Andreyev, K. Spohr
University of the West of Scotland, Paisley, UK

Outline of the talk

We would like to propose a gamma spectroscopic studies of low-lying structures in $^{127\text{-}134}$Sb, by employing incomplete fusion reactions induced by the radioactive beams of $^{126\text{-}133}$Sn on a ^{7}Li target.

The nuclei will be populated in a ^{7}Li(^{A}Sn,α2n)$^{A+1}$Sb process.

129Sb 4.40 H β-: 100.00%	130Sb 39.5 M β-: 100.00%	131Sb 23.03 M β-: 100.00%	132Sb 2.79 M β-: 100.00%	133Sb 2.5 M β-: 100.00%	134Sb 0.78 S β-: 100.00%
128Sn 59.07 M β-: 100.00%	129Sn 2.23 M β-: 100.00%	130Sn 3.72 M β-: 100.00%	131Sn 56.0 S β-: 100.00%	132Sn 39.7 S β-: 100.00%	133Sn 1.45 S β-: 100.00% β-n: 0.08%

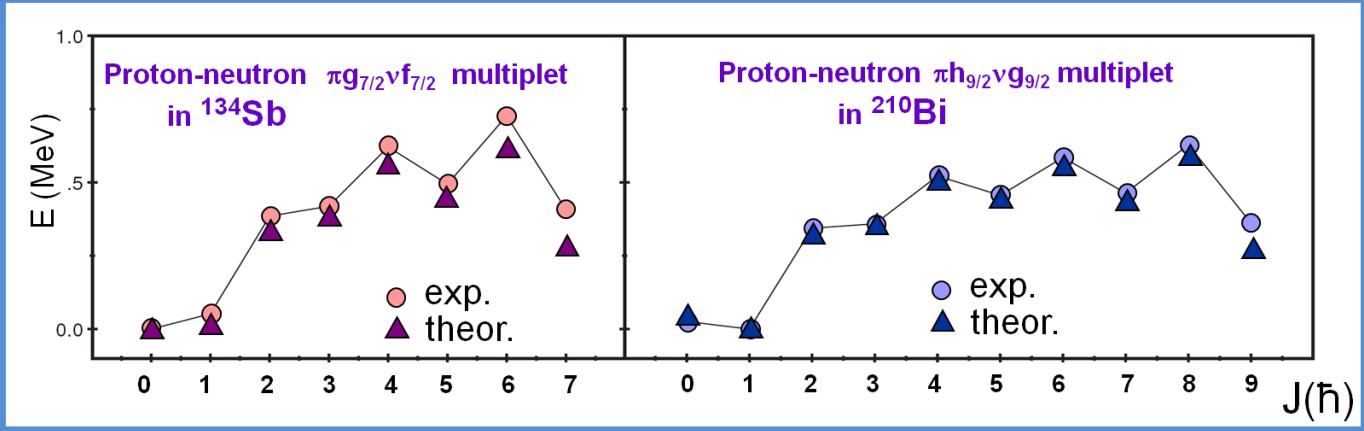
I will discuss:

1. Physical motivation
2. Current experimental information
3. ^{7}Li(^{A}Sn,α2n)$^{A+1}$Sb reaction
4. Advantages of the suggested method

Realistic shell model calculations around ^{132}Sn

The realistic shell model calculations had opened a „new chapter" in nuclear structure physics. **Parameter-free** calculations around doubly-magic nuclides become possible. **No adjustment** of interaction is necessary to obtain the **excellent agreement** with the experimental data.

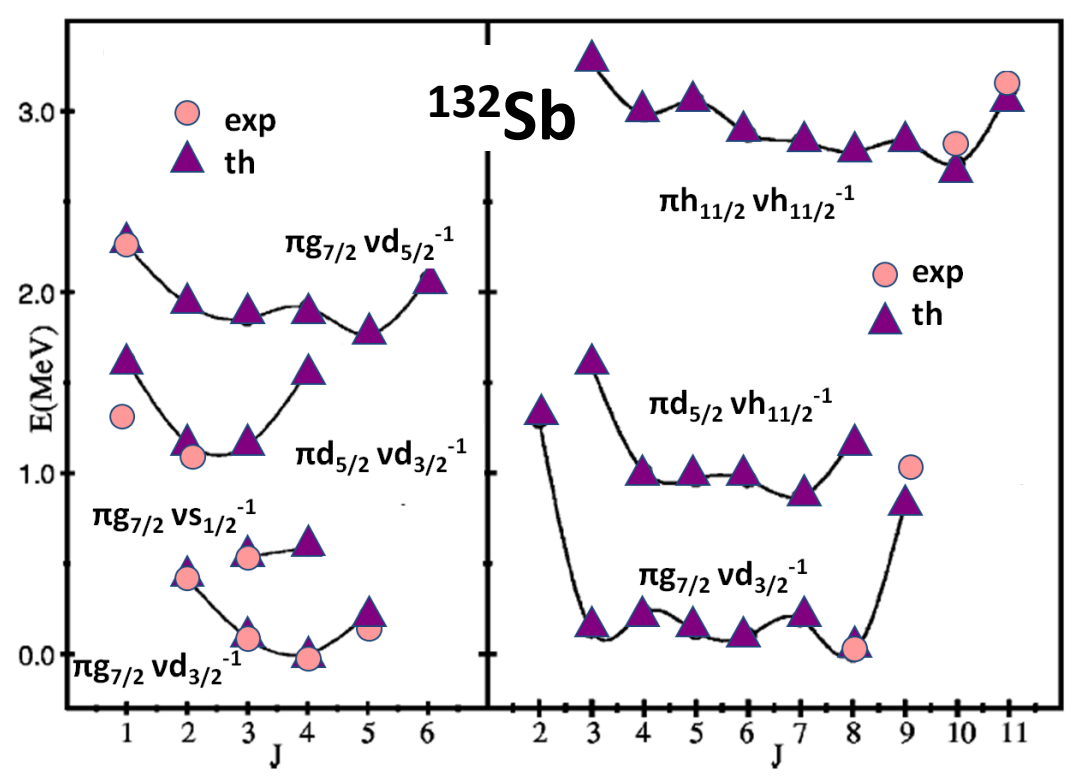
The nuclides from the vicinity of ^{132}Sn and ^{208}Pb provide the best data to test the experimental data against theoretical predictions. **However the experimental information is very sparse.**



L. Coraggio, A. Covello, A. Gargano, N. Itaco, PRC **80**, 021305(R) (2009)

Available experimental information

The situation results from the inaccessibility of the region in standard fusion-evaporation or deep-inelastic reactions with stable projectiles and targets. What little is known comes mainly from beta-decay studies or spectroscopic investigations of fission products.



L. Coraggio et. al. PRC **66**, 064311 (2002)

Incomplete fusion reactions

The nuclei of interest will be populated in a reaction:

$^{7}Li(^{A}Sn,\alpha 2n)^{A+1}Sb$

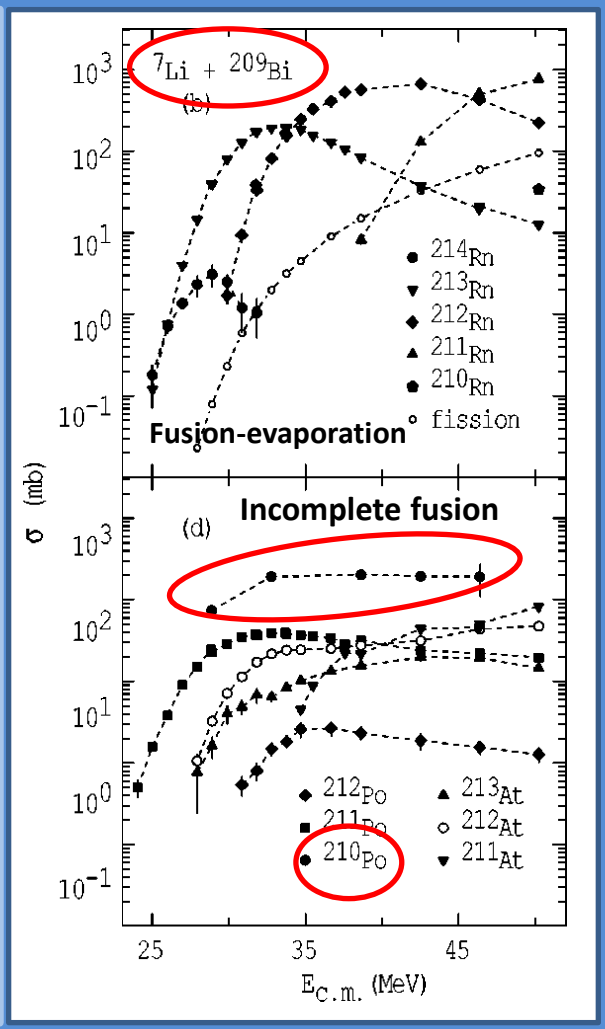
There is a significant probability of a ^{7}Li beam nucleus breaking up, with a triton being captured while α particle is emitted. Reaction offer access to states at relatively high angular momentum.

Clark et. al. [Cla] investigated the population of nuclei formed in reactions involving ^{7}Li beams on targets of ^{160}Gd and ^{184}W.

- cross-section for the (^{7}Li,α2n) process at beam energies of a few MeV above Coulomb barrier is of order of **100 mb**
- exceeds by 1-2 orders of magnitude the predictions of a standard fusion-evaporation model
- can be explained by using the Wilczynski binary transfer model + standard evaporation model.

[Cla] R. M. Clark et. al. PRC **72**, 054605

Dasgupta *et. al.* PRC **66**, 041602(R)



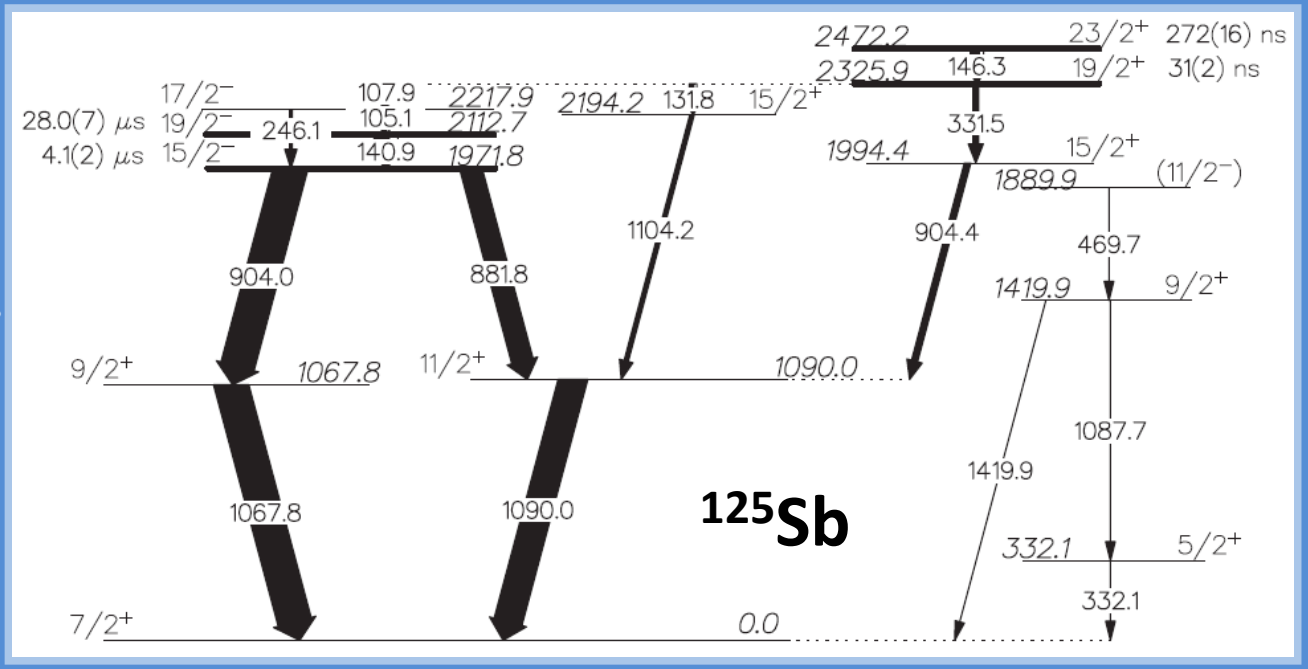
Incomplete fusion reactions

Recently, excited states in ^{123,125}Sb with spins up to 23/2 have been studied following the ^{122,124}Sn(^{7}Li,α2n)^{123,125}Sb incomplete fusion reaction at beam energy of 35, 37 MeV.

D. S. Judson et. al. PRC **76**, 054306

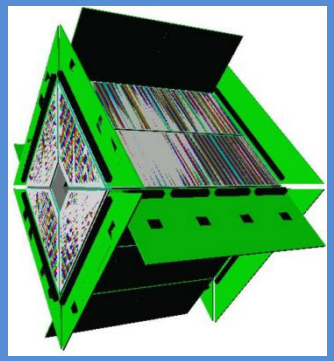
The (^{7}Li,α2n) incomplete fusion reactions have been used to populate high-spin states in ^{121,123}Sb [Wat] and in ^{179}Hf [Mul].

[Wat] H. Watanabe et. al. PRC **79**, 024306
[Mul] S. M. Mullins et. al. PRC **61**, 044315



Experimental setup

SPES exotic beams for science



TRACE - Tracking Array for light Charged particle ejectiles

^{A}Sn beam
500-600 MeV

Recoil cone < 3°

^{A}Sn → ^{7}Li

α

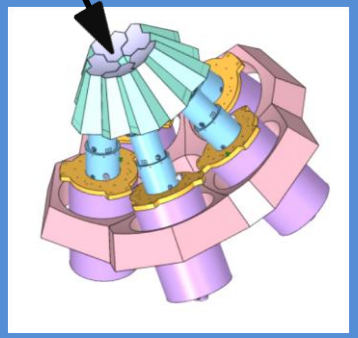
$^{A+1}$Sb*

$^{A+1}$Sb

γ-rays

^{7}Li target

AGATA



Details of an experiment

Beam energy: **500-600 MeV**
Target thickness: **1 mg/cm²**
We assume :

- **100 mb** for the (^{7}Li,α2n) channel cross-section
- **50%** efficiency of AGATA array trigged by charged particle detector

SPES exotic beams for science

Element	particles/s
^{127}Sn	8.16E+08
^{128}Sn	6.36E+08
^{129}Sn	3.50E+08
^{130}Sn	1.58E+08
^{131}Sn	6.83E+07
^{132}Sn	3.11E+07
^{133}Sn	2.76E+06

This gives:

- **Few thousands of gamma singles or double gamma coincidence events per second for $^{127\text{-}130}$Sn beam**
- **For the reaction induced by the ^{131}Sn beam leading to ^{132}Sb recorded gamma-gamma events will be of the order of few hundreds per second**
- **For a ^{133}Sn beam we get one order of magnitude lower for the counting rate for ^{134}Sb.**

Advantages of the proposed experiment

- The very inverse kinematics guarantees that the product nuclei all travel downstream in a very small recoil cone, thus Doppler correction do not require recoil detection.

- Reaction channel of interest will be uniquely associated with the emission of an α particle.

- The same reactions in their ^{7}Li(^{A}Sn,p*x*n)^{A}Te channel will also populate with appreciable yield the Te nuclei with A=129-136. The emitted protons may be used as event tags.

Presented counting rate estimates give us confidence that detailed gamma-ray spectroscopic studies of the low lying structures in $^{127\text{-}132}$Sb will be possible at SPES. Study of more exotic species possible with SPIRAL2.