Neutron emission from unbound states in ^{135}Sn

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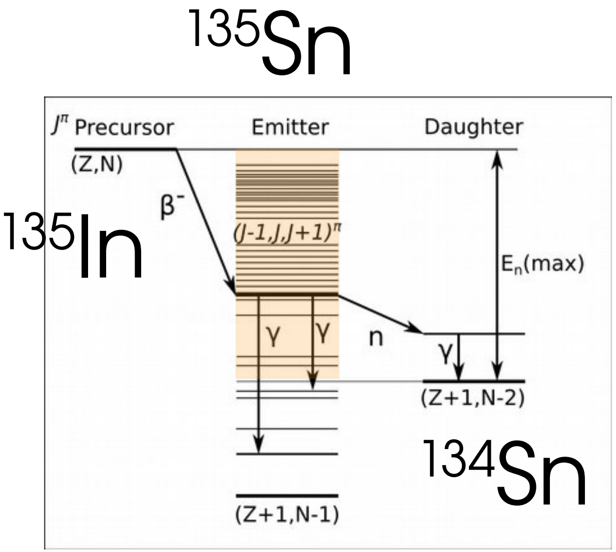
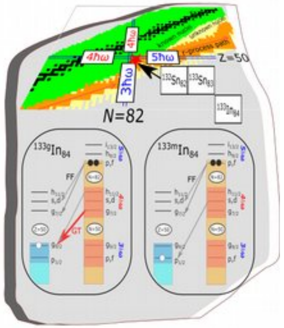


Previous IDS decay studies of ^{133}In, ^{134}In and ^{135}In

Neutron spectroscopy: (final edits)



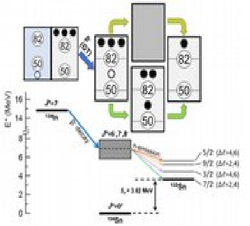
The decay of ^{133}In: a rosetta stone for the r-process nuclei

Z. Y. Xu,[1] M. Madurga,[1] R. Grzywacz,[1,2] T. T. King,[1] A. Algora,[3,4] A. N. Andreyev,[5,6] J. Benito,[7] T. Berry,[8]

Stirred or shaken? Evidence of non-statistical neutron emission following beta-decay near doubly magic ^{132}Sn

J. Heideman,[1] R. Grzywacz,[1,2] Z. Y. Xu,[1] M. Madurga,[1] A. Algora,[3] A. N. Andreyev,[4] J. Benito,[5] T. Berry,[6] M. J.

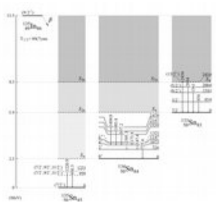
Gamma-ray spectroscopy:



β decay of 133 In: γ emission from neutron-unbound states in ^{133}Sn

M. Piersa, A. Korgul, L. M. Fraile, J. Benito...

Phys. Rev. C 99, 024304 (2019)



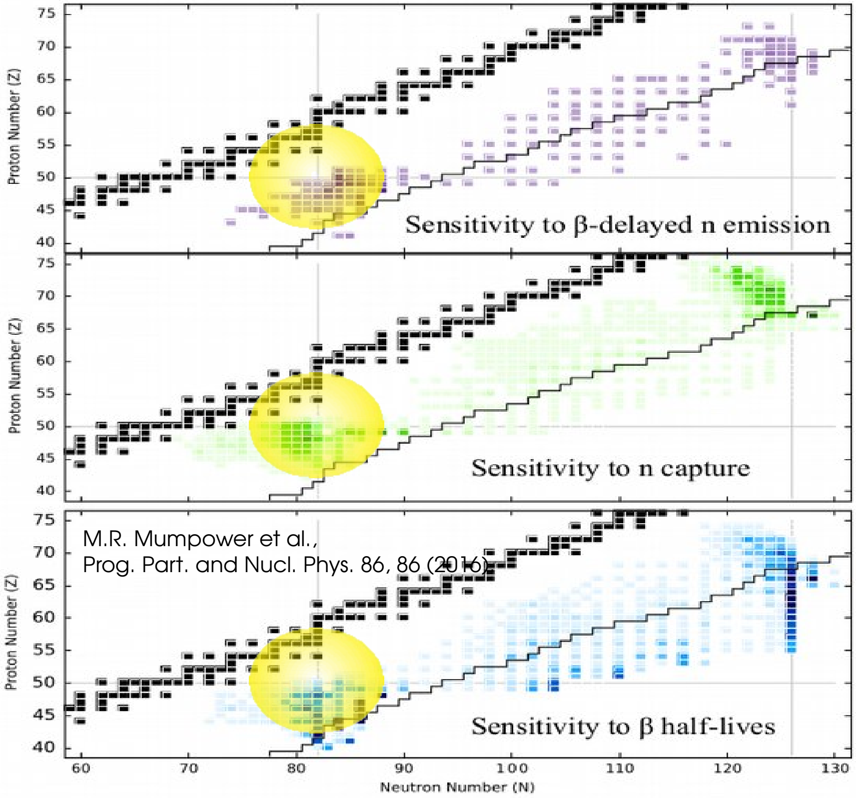
First β-decay spectroscopy of ^{135}In and new β-decay branches of ^{134}In

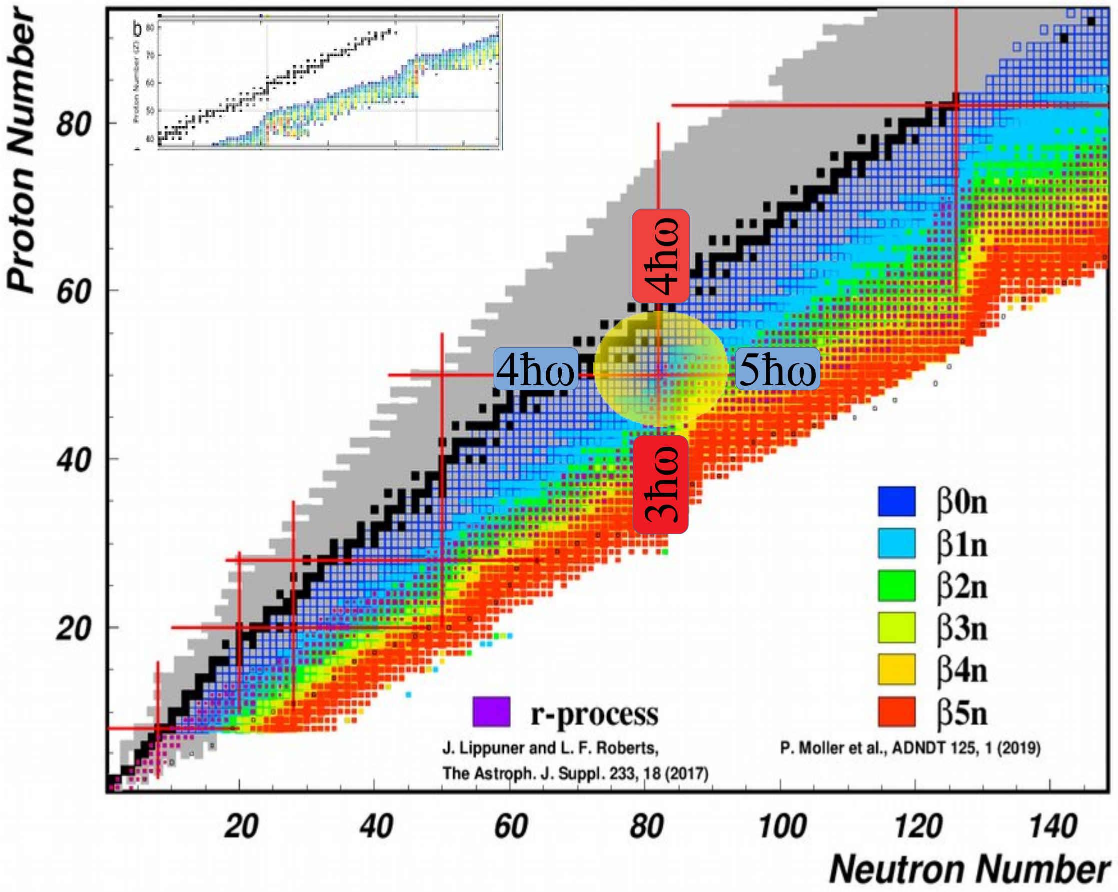
M. Piersa-Siłkowska,[1,*] A. Korgul,[1] J. Benito,[2] L. M. Fraile,[2,3] E. Adamska,[1] A. N. Andreyev,[4] R. Álvarez-Rodríguez,[5]

Phys. Rev. C 104, 044328, (2021)

The ^{132}Sn region: nuclear structure meets astrophysics

Validate nuclear structure models with large pn assymetry.





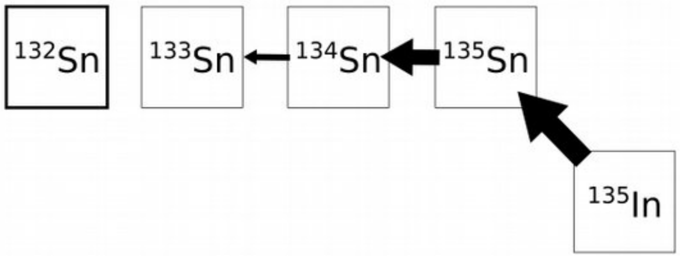
Uncomplicated decays near ^{132}Sn

Experiment will probe directly the underpinning of physics which determines beta decay properties of neutron rich nuclei.

Verification of models of beta-delayed neutron emission (nuclear structure, astrophysics and applications).
Studies of excited states in Sn isotopes.

Goals of the proposal:

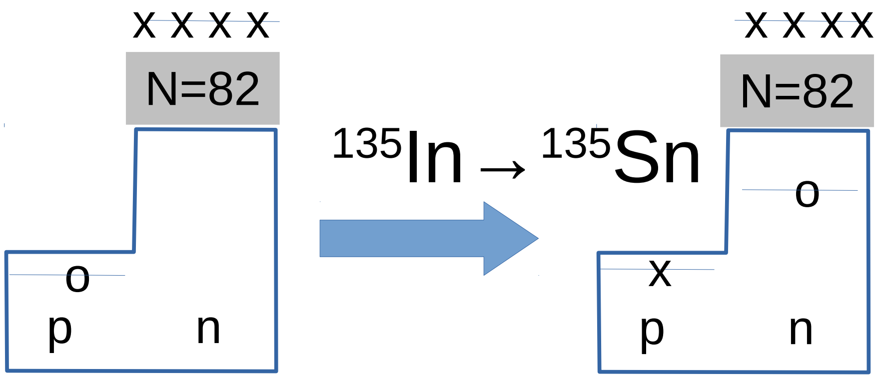
i. Measurement of the main allowed Gamow-Teller decay channel $\nu g_{7/2} \rightarrow \pi g_{9/2}$ via its neutron emission.
ii. Direct identification of the First-Forbidden transitions to neutron unbound states in ^{135}Sn.
iii. Two-neutron emission from the excited states in ^{135}Sn.
iv. Expansion of the ^{134}Sn and ^{135}Sn level schemes.

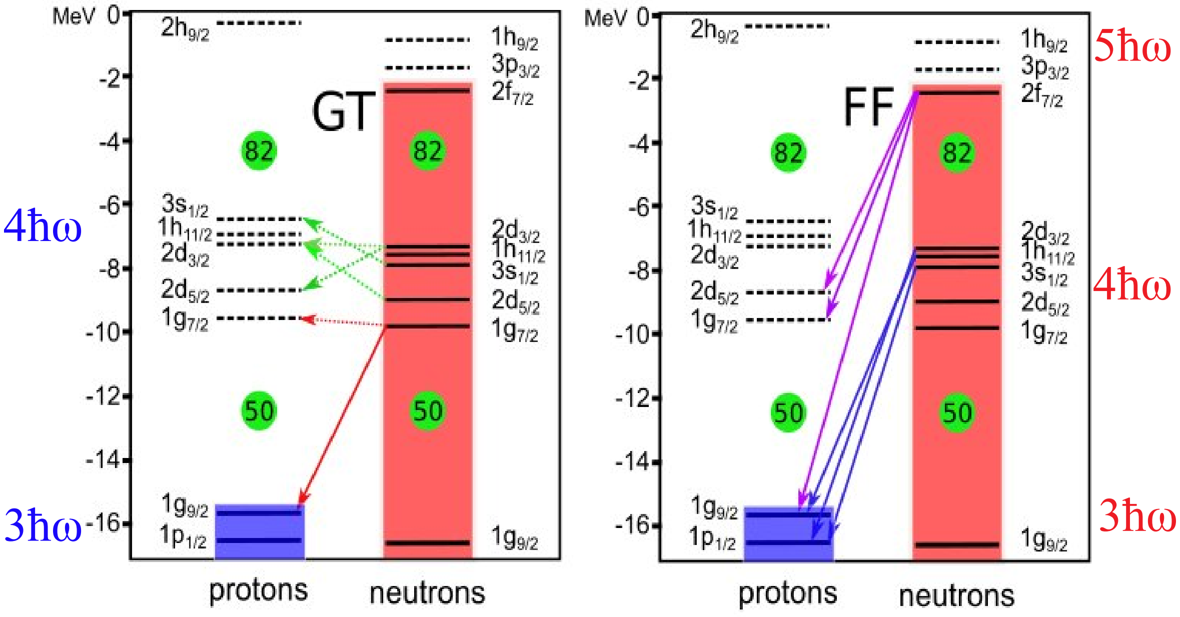


The microscopic origins of nuclear lifetimes Allowed GT and FF transitions near ^{132}Sn

Dominant transitions

$$\text{GT: } \nu g_{7/2} \rightarrow \pi g_{9/2}$$





$$\text{FF: } \nu h_{11/2} \rightarrow \pi g_{9/2} \qquad \nu f_{7/2} \rightarrow \pi g_{7/2}$$

Beta decay near ^{132}Sn (Z<50) - shell model

^{88}Sr core (38 protons and 50 neutrons) + N3LO nn forces (Kshell)

neutrons $0g_{7/2}$, $1d_{5/2}$, $1d_{3/2}$, $2s_{1/2}$, $0h_{11/2}$, $1f_{7/2}$

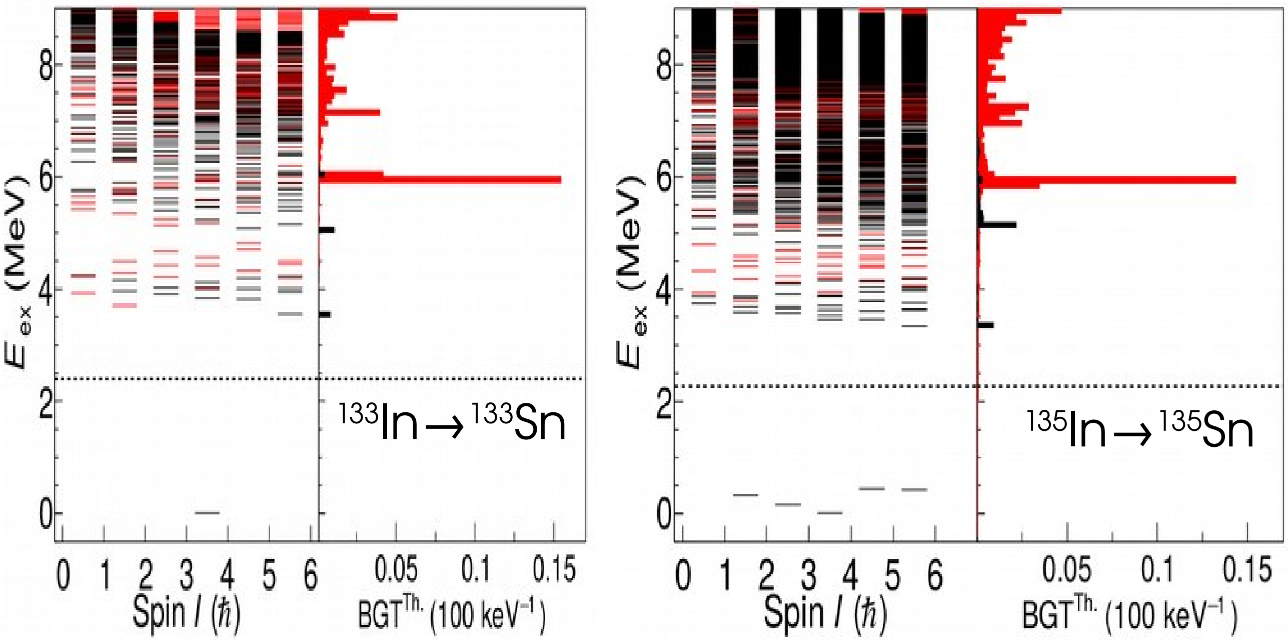
protons $1p_{1/2}$, $0g_{9/2}$, $0g_{7/2}$, $1d_{5/2}$, $1d_{3/2}$, $2s_{1/2}$

The decay of ^{133}In: a rosetta stone for the r-process nuclei

Z. Y. Xu,[1] M. Madurga,[1] R. Grzywacz,[1,2] T. T. King,[1] A. Algora,[3,4] A. N. Andreyev,[5,6] J. Benito,[7] T. Berry,[8]

From ^{133}In to ^{135}In

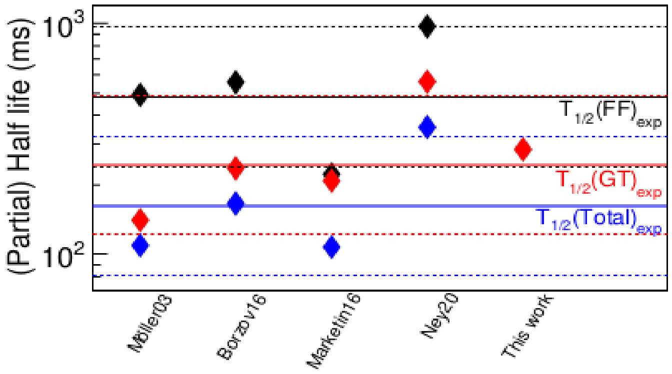
- nearly identilcal GT $\nu g_{7/2} \rightarrow \pi g_{9/2}$ and FF $\nu h_{11/2} \rightarrow \pi g_{9/2}$
- larger expected (FF) $\nu f_{7/2} \rightarrow \pi g_{7/2}$ (due to increased neutron number)
- increased contribution of Z=50 core breaking GT transitions, (increased role of 2n emission ?)
- very smal (FF) $\nu f_{7/2} \rightarrow \pi g_{9/2}$ (g.s. to g.s)

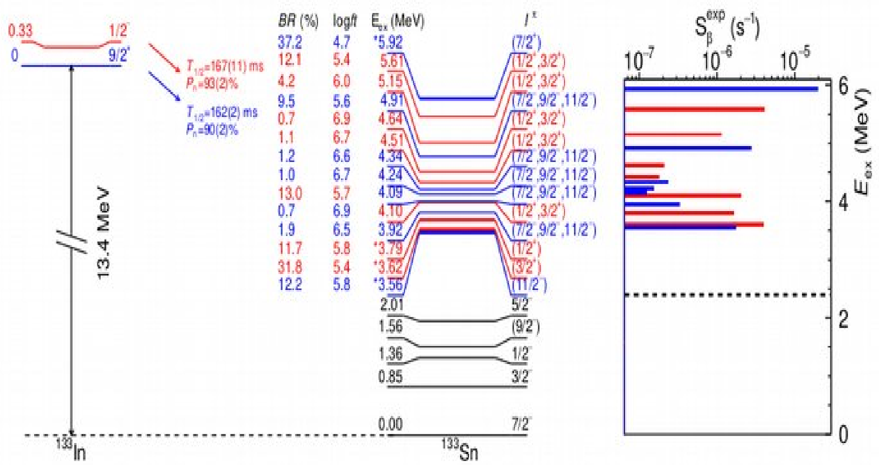


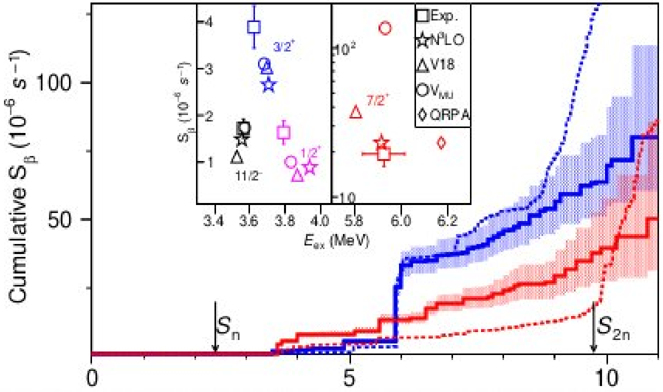
The decay of ^{133}In - a rosetta stone for the r-process nuclei

- Key nucleus to test nuclear models of n-rich nuclei
- Quantified role of "elementary" GT and FF transitions
- Candidate for the ab-initio calculations of GT strength

- Excellent agreement with N3L0 shell-model predictions (q = 0.6)
- Other interactions drastically overestimated the main GT strength
- Fragmentation of the wavefunction close to ^{132}Sn.
- Global models do not describe the data well
- Only Borzow QRPA predicted correctly the partial FF and GT lifetimes







The decay of ^{133}In: a rosetta stone for the r-process nuclei

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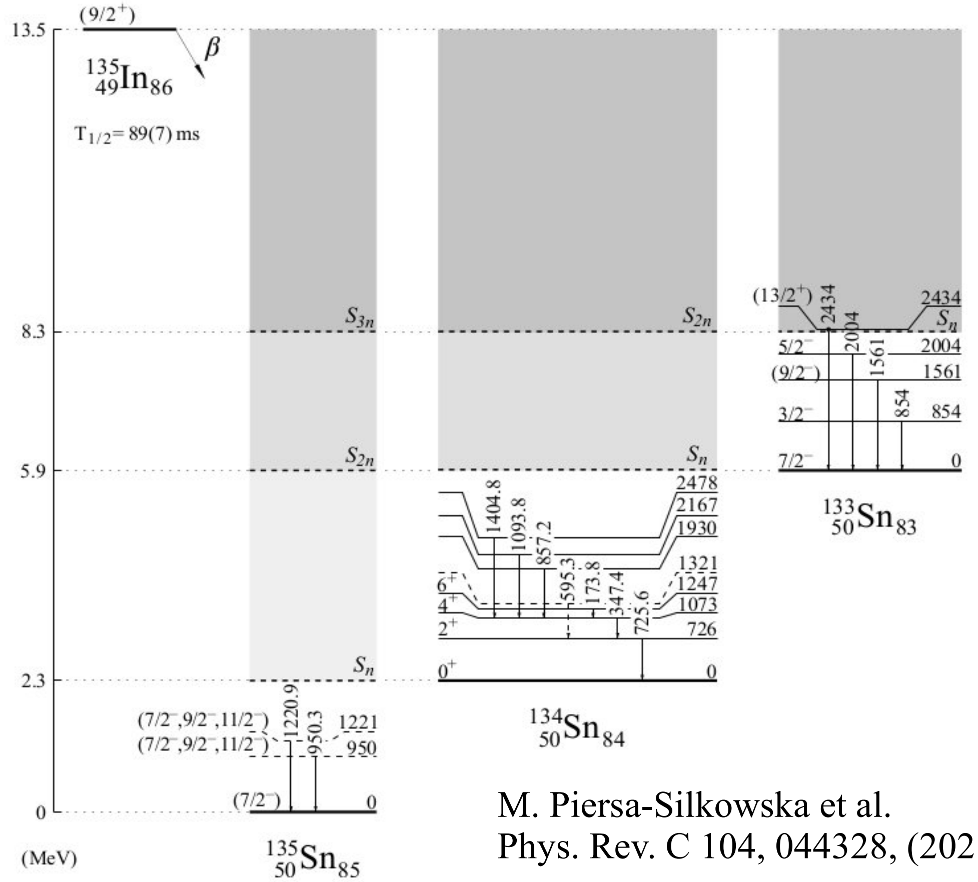
^{135}In decay: gamma-ray spectroscopy

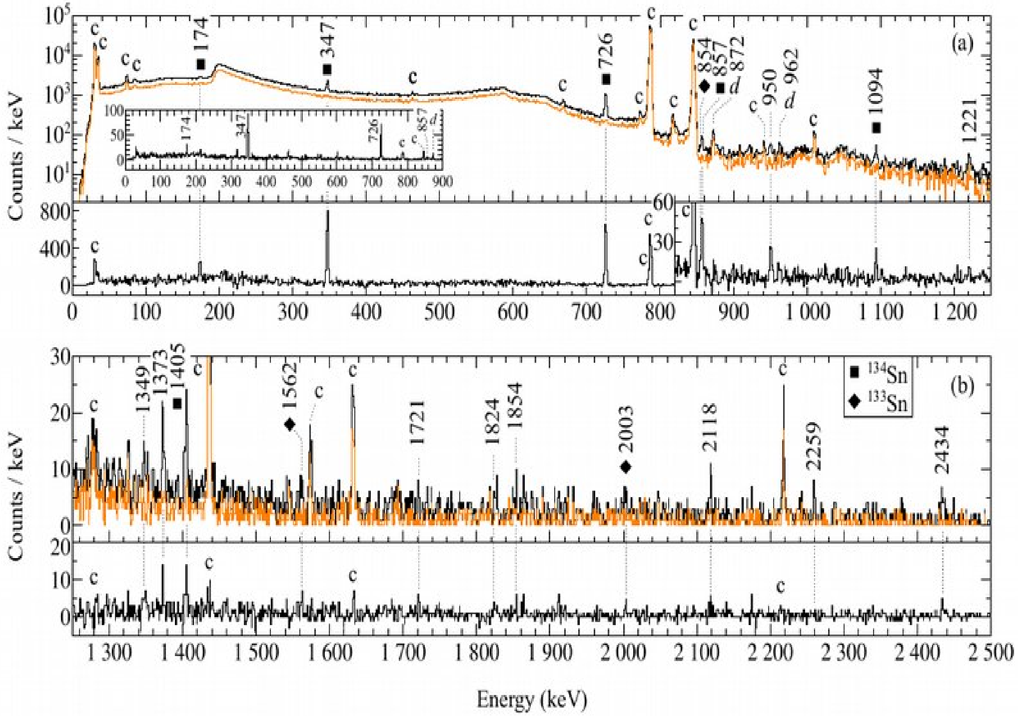


M. Piersa-Silkowska et al.
Phys. Rev. C 104, 044328, (2021)

Excited states in:

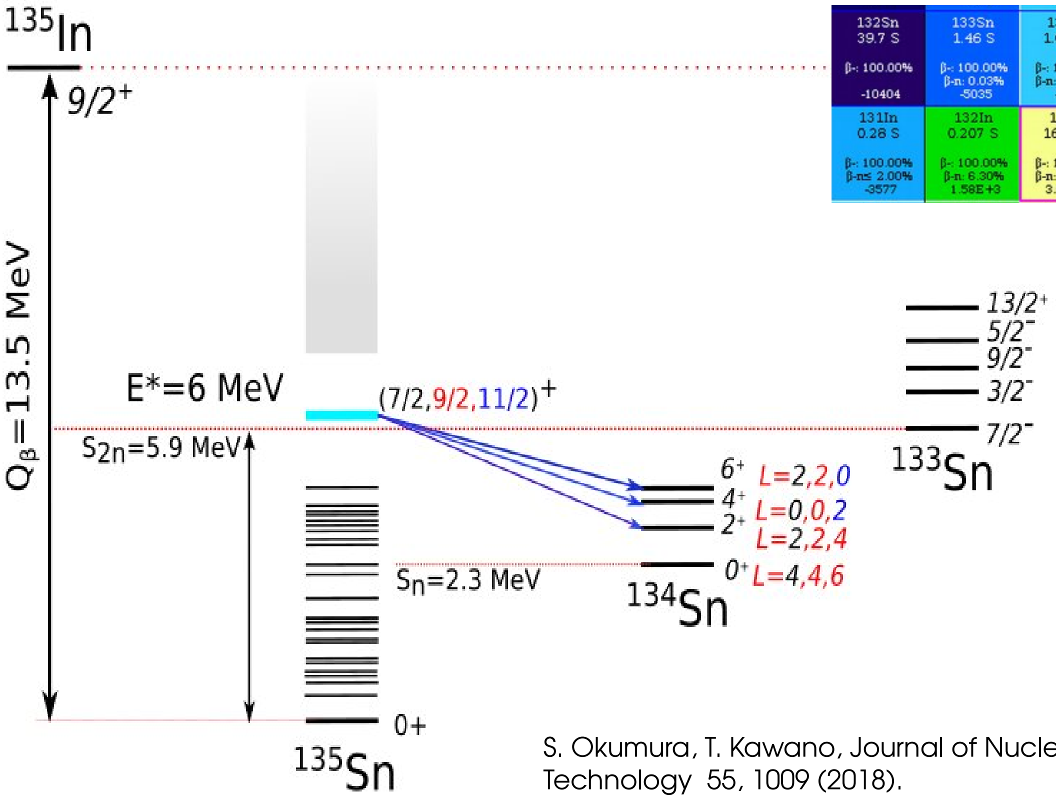
^{135}Sn (β0n), ^{134}Sn (β1n), ^{133}Sn(β2n)

Contamination from ^{135}Cs^{m} ($T_{1/2}$=53m, E*=1.6 MeV)

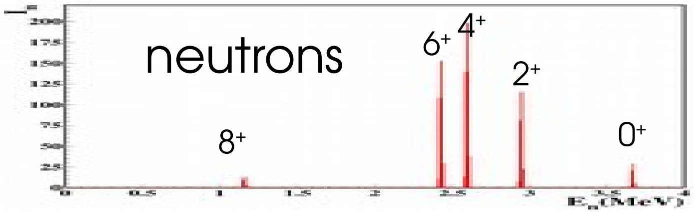


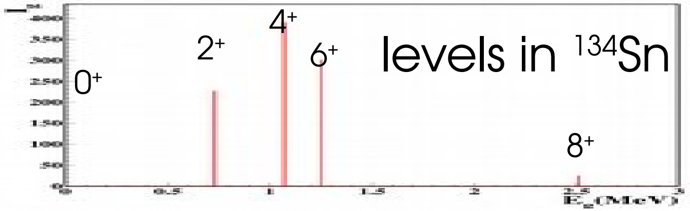
Delayed neutron emission from ^{135}In
neutron -gamma cascades

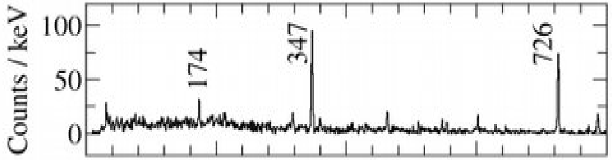
Hauser-Feshbach predictions of the decay pattern of an isolated GT state.

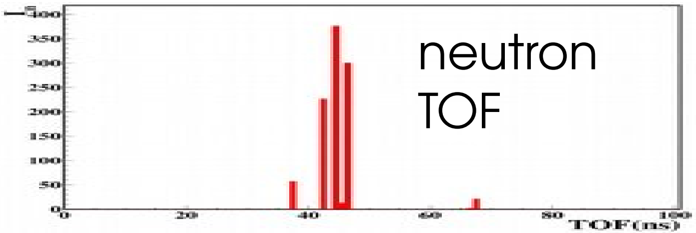


132Sn 39.7 S β-: 100.00% -10404	133Sn 1.46 S β-: 100.00% β-n: 0.03% -5035	134Sn 1.050 S β-: 100.00% β-n: 17.00% -2941	135Sn 530 MS β-: 100.00% β-n: 21.00% 2149	136Sn 0.290 S β-: 100.00% β-n: 28.00% 2.0E+3
131In 0.28 S β-: 100.00% β-n≤ 2.00% -3577	132In 0.207 S β-: 100.00% β-n: 6.30% 1.58E+3	133In 165 MS β-: 100.00% β-n: 85.00% 3.66E+3	134In 140 MS β-: 100.00% β-n: 65.00% 8.7E+3	135In 92 MS β-: 100.00% β-n 8.2E+3



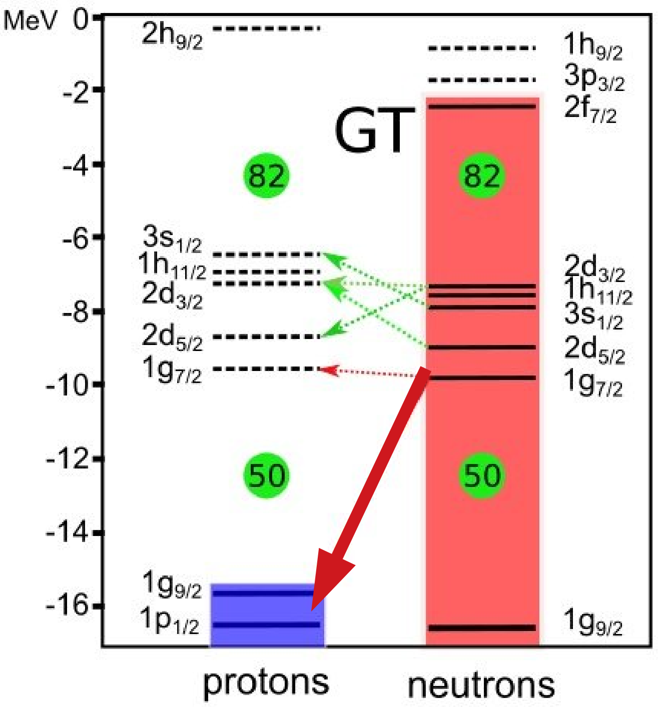


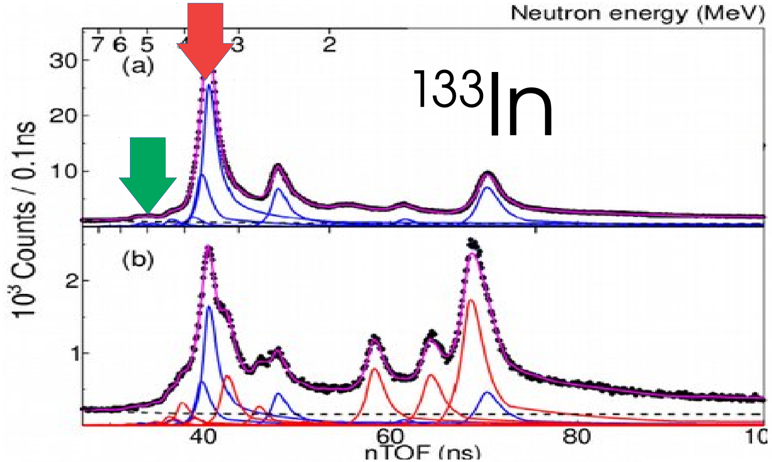


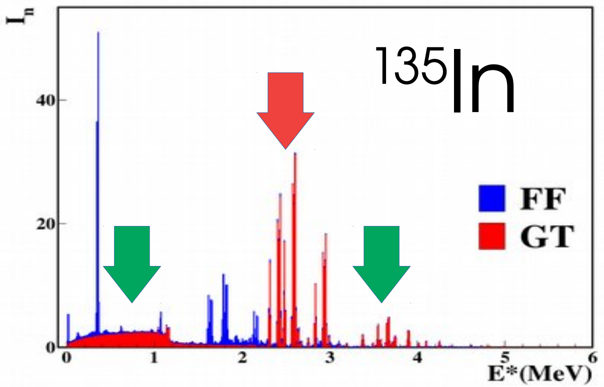


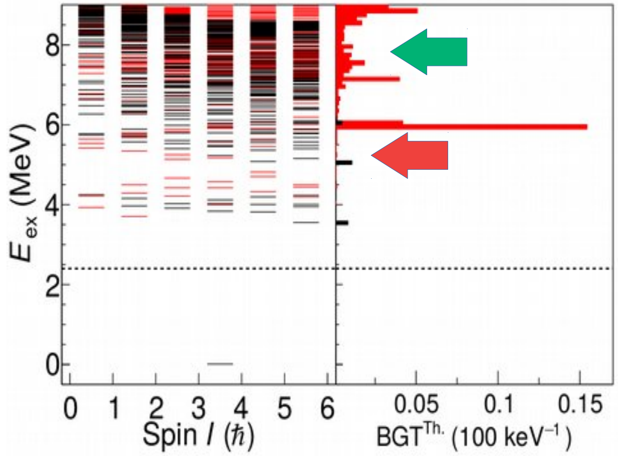
S. Okumura, T. Kawano, Journal of Nuclear Science and Technology 55, 1009 (2018).

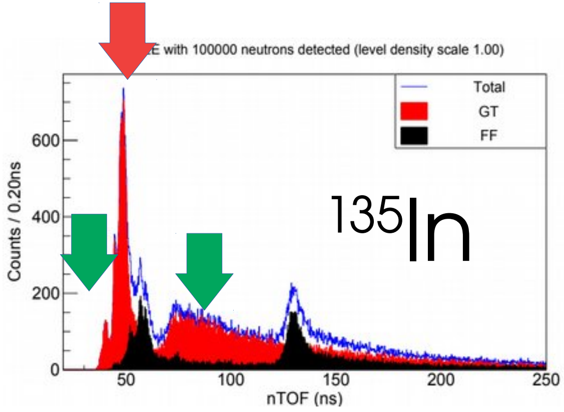
Neutron spectroscopy (GT decays)



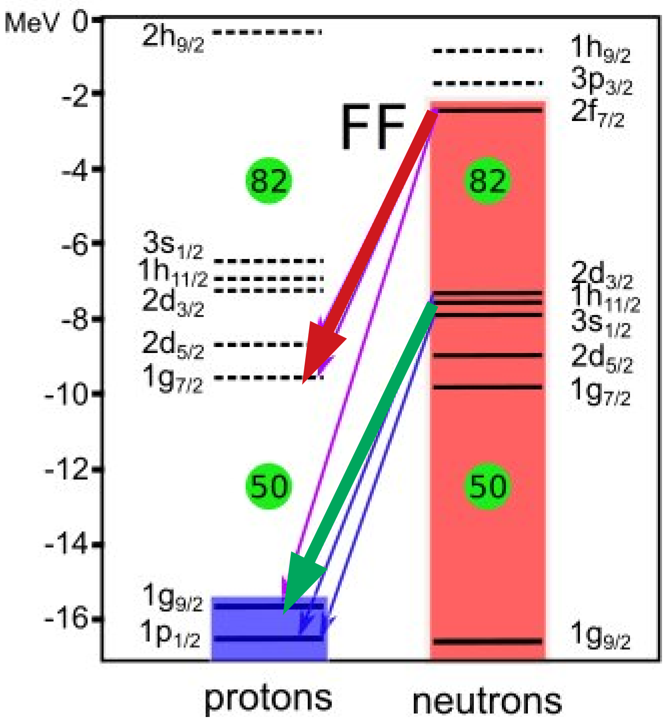


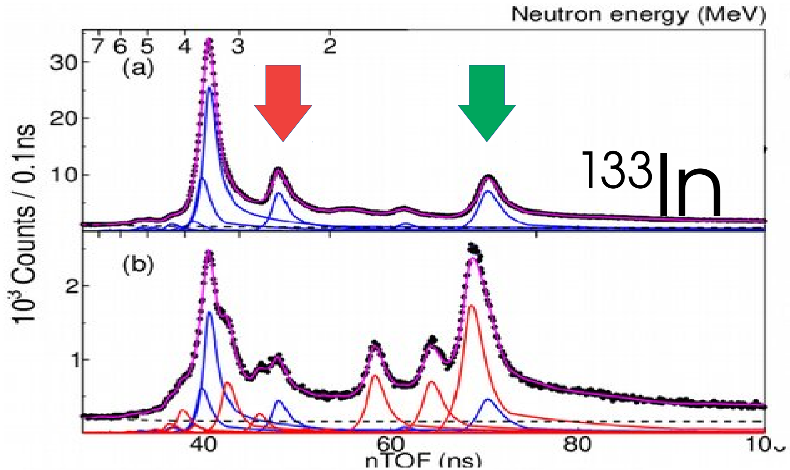


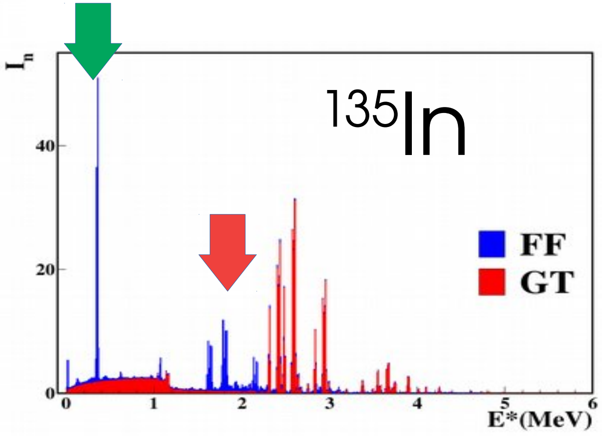


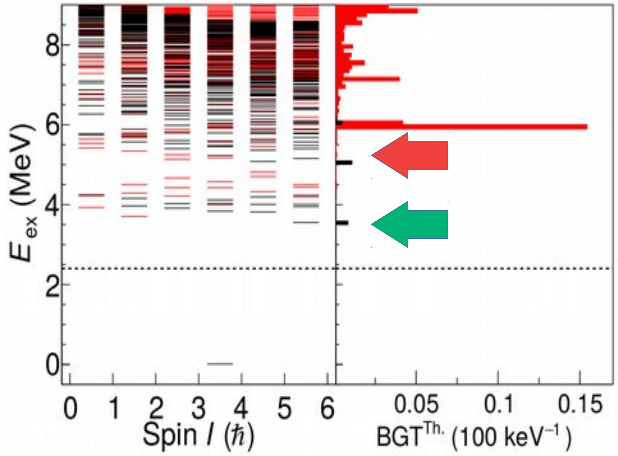


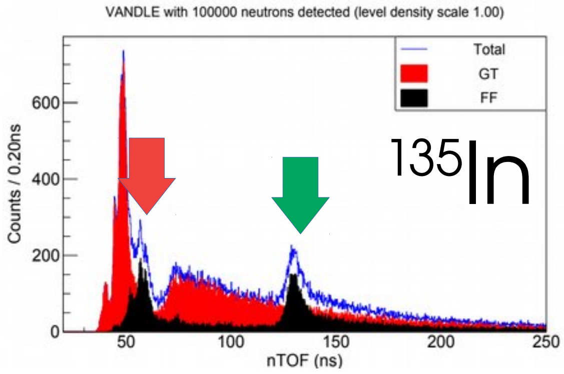
Neutron-spectroscopy (FF decays)







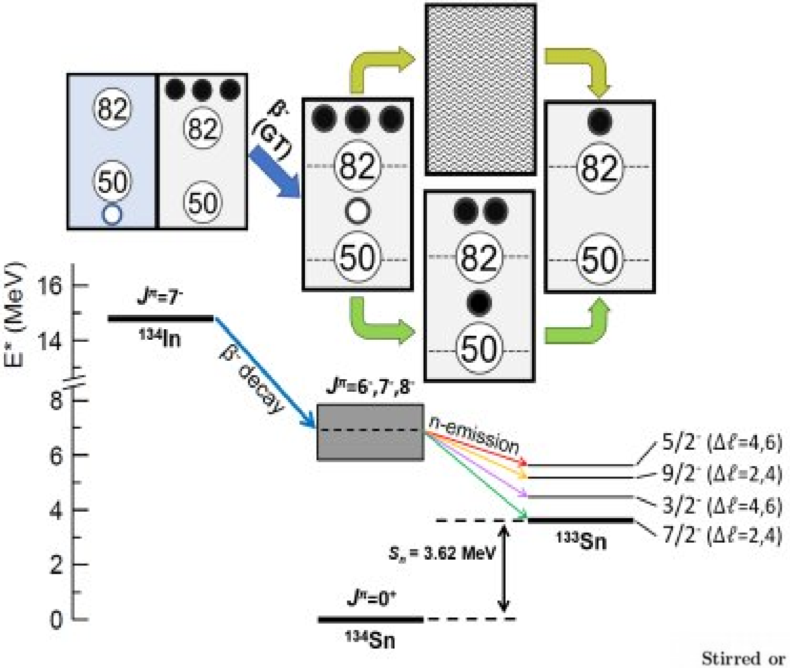


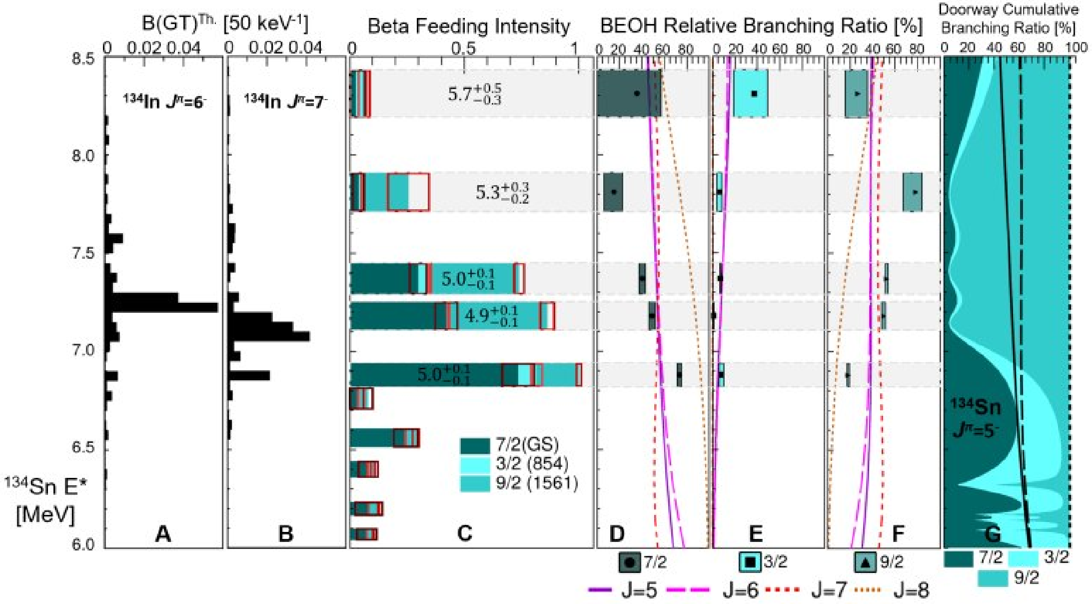


Compound or direct ?

Is the compound nucleus stage a necessary part of the neutron emission process ?
Population of excites states in ^{133}Sn cannot be explained by the statistical model under the compound nucleus assumption.

$^{134}In \rightarrow ^{134}Sn \rightarrow ^{133}Sn$

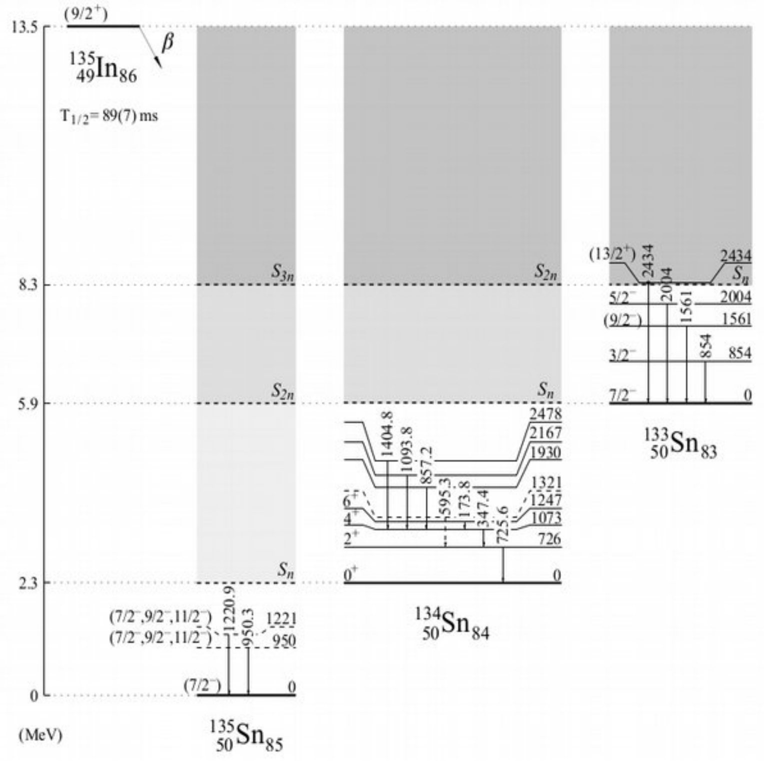




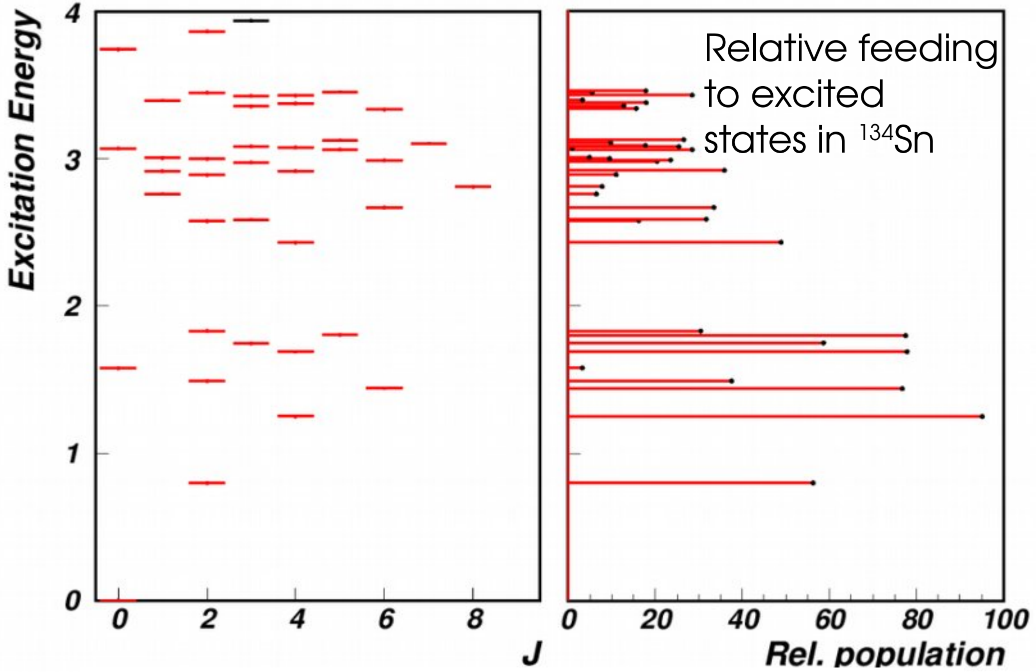
Stirred or shaken? Evidence of non-statistical neutron emission following beta-decay near doubly magic ^{132}Sn

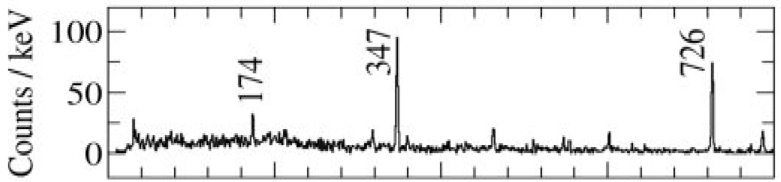
J. Heideman,[1] R. Grzywacz,[1,2] Z. Y. Xu,[1] M. Madurga,[1] A. Algora,[3] A. N. Andreyev,[4] J. Benito,[5] T. Berry,[6] M. J.

Excited states in ^{134}Sn: statistical model predictions



M. Piersa-Silkowska et al.
Phys. Rev. C 104, 044328, (2021)



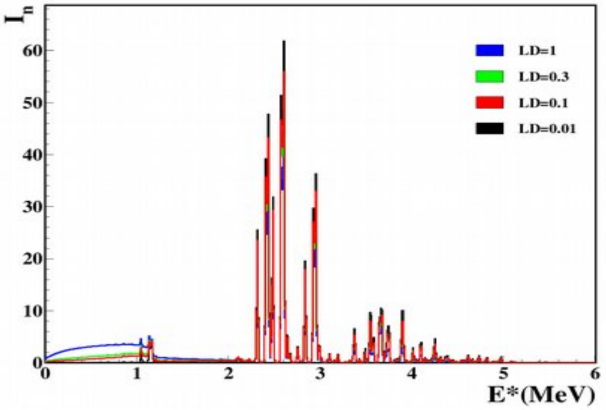


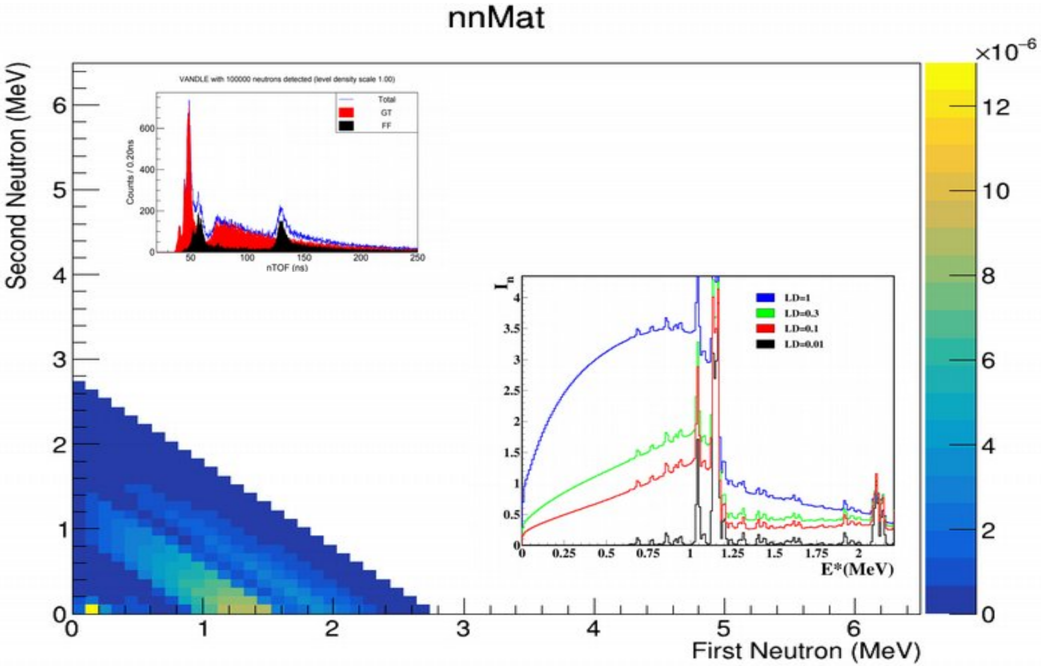
β2n spectroscopy of ^{135}In decay

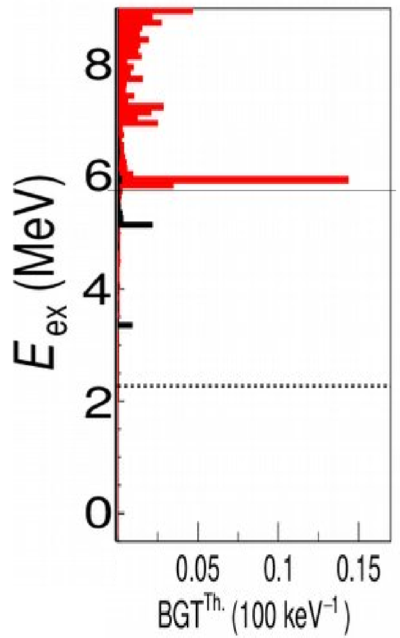
Large:

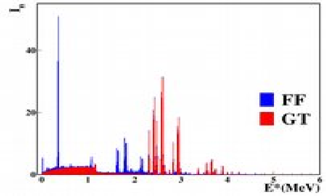
$Q_\beta - S_{2n}$=7.6 MeV

P_{2n}~0.1, P_{1n}~0.9





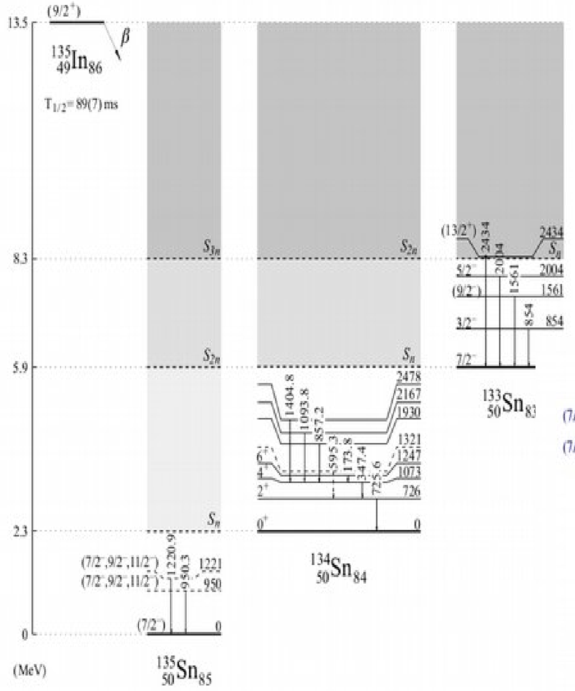




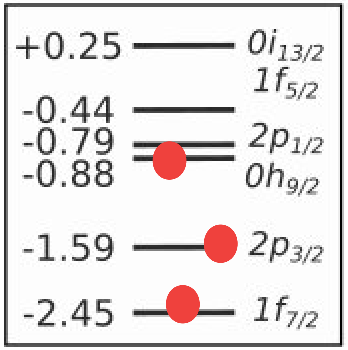
- statistical model predicts only P_{2n}~6% with “nominal” level-density parameter at ^{134}Sn
- evaluate 1n vs 2n competition
- relative population of excited states in ^{133}Sn

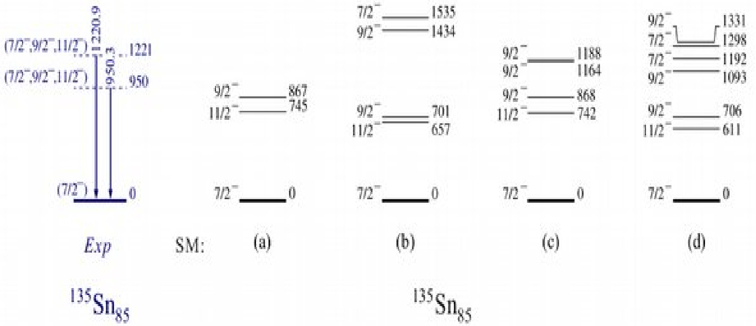
Excited states in ^{135}Sn from forbidden transitions

Shell model states in ^{135}Sn :
very mixed neutron configurations.

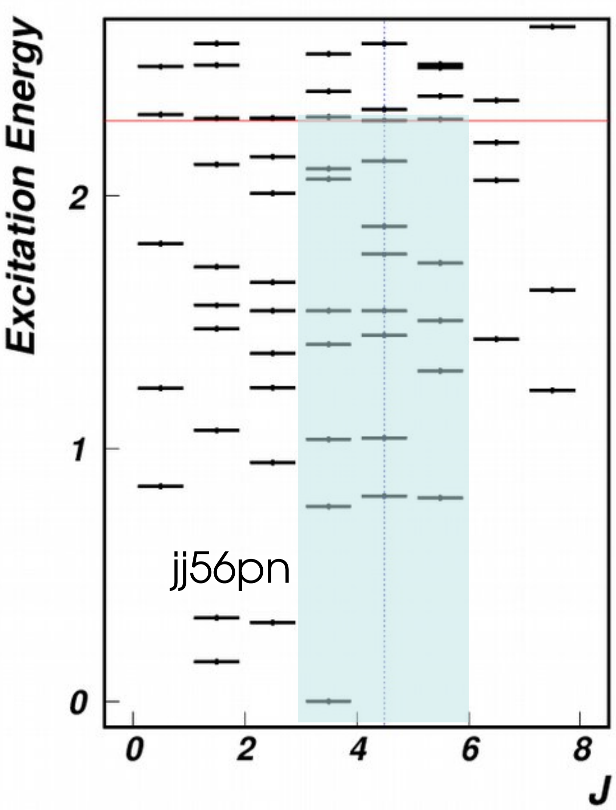


Neutron particle states:

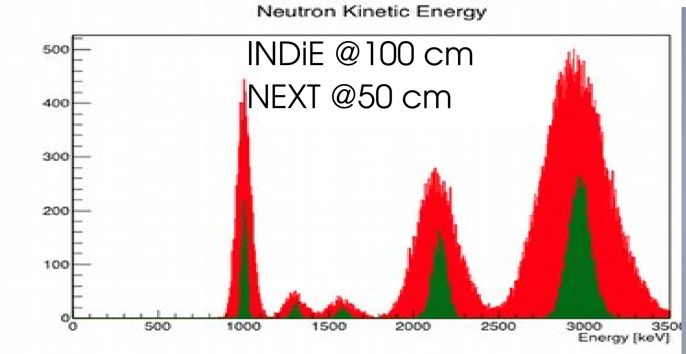


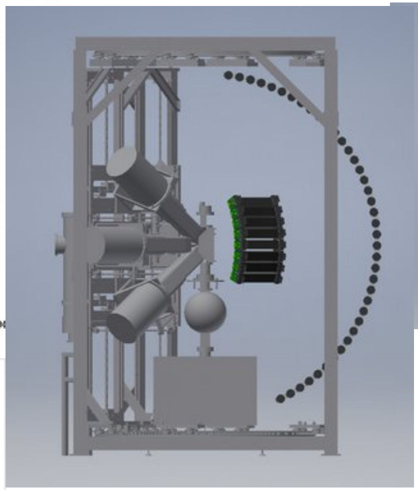


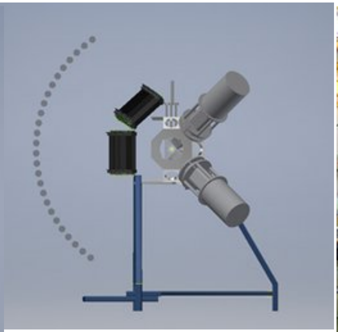
9/2+→ (7/2,9/2,11/2)-

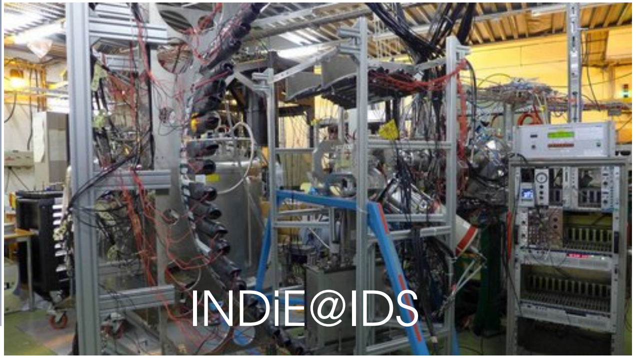


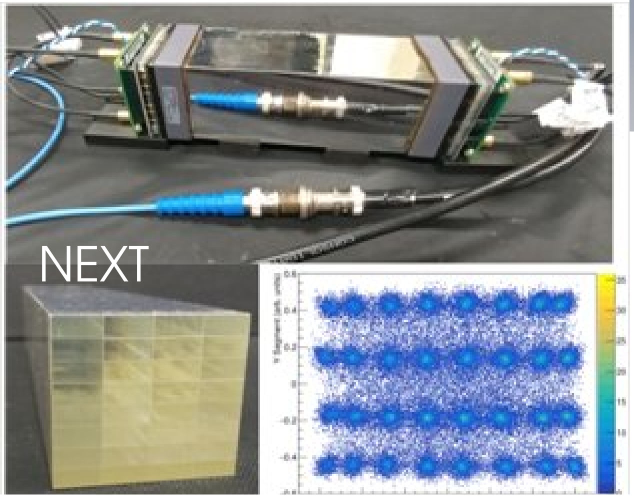
INDiE and NEXT arrays at IDS

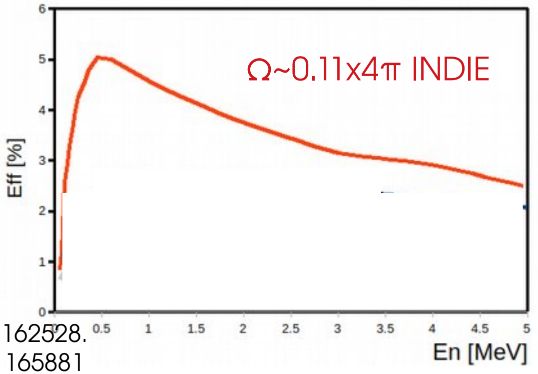


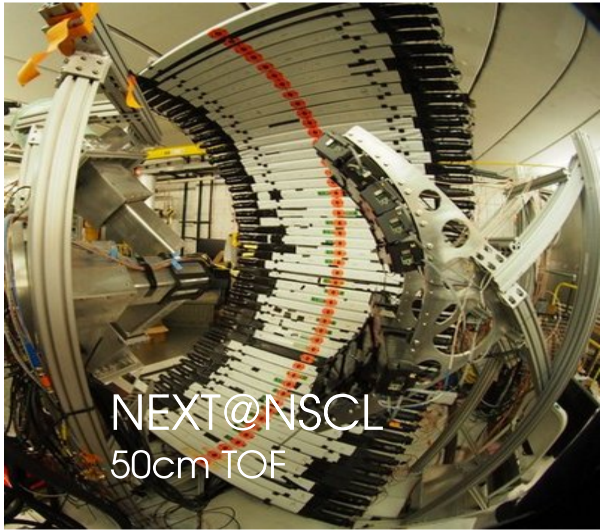












J. Heideman et al. Nuclear Instruments and Methods A, 946 (2019) 162528.
S. Neupane et al.Nuclear Instruments and Methods A 1020, (2021), 165881

Beam time request

Collect statistics sufficient to construct nn and nγ cascades.

15 shifts to collect ~1x10^5 neutrons ^{134}In (INDiE)
During the 15 shifts we expect to collect about 100-200 two-neutron events.

How similar are ^{135}In and ^{133}In decays (FF and GT) ?
Evidence for non-statistical neutron (1n/ 2n) emission from ^{135}Sn ?

IDS with RILIS uniquely positioned to perform the high statistics 1n/2n spectroscopy of ^{135}In decay

Goals of the proposal:

- Measurement of the main allowed Gamow-Teller decay channel $\nu g_{7/2} \rightarrow \pi g_{9/2}$ via its neutron emission.
- Direct identification of the First-Forbidden transitions to neutron unbound states in ^{135}Sn.
- Two-neutron emission from the excited states in ^{135}Sn.
- Expansion of the ^{134}Sn and ^{135}Sn level schemes.

	P_{1n}(%)	Yield (ion/μC)	IDSND Eff	Neutrons (1/h)	Shifts	Target	Source
^{135}In	90%	4	0.04	700	15	UC_x+n.c.	Hot Ta line and cavity + RILIS
^{49}K	86%	>1000	0.04	>1.0 10^5	1	UCx	Hot Ta line and cavity