Beta-delayed neutron emission of ^{134}In and search for $i_{13/2}$ single particle neutron state in ^{133}Sn

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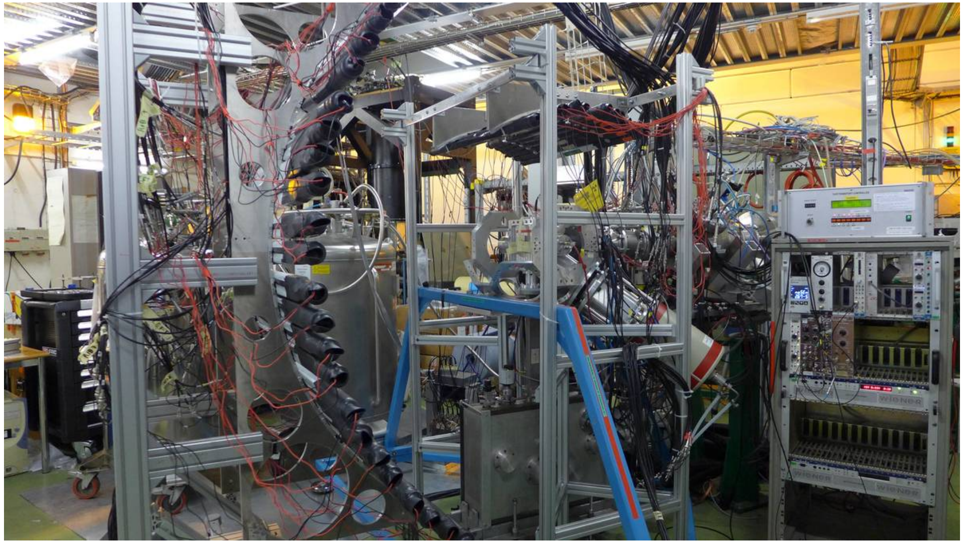
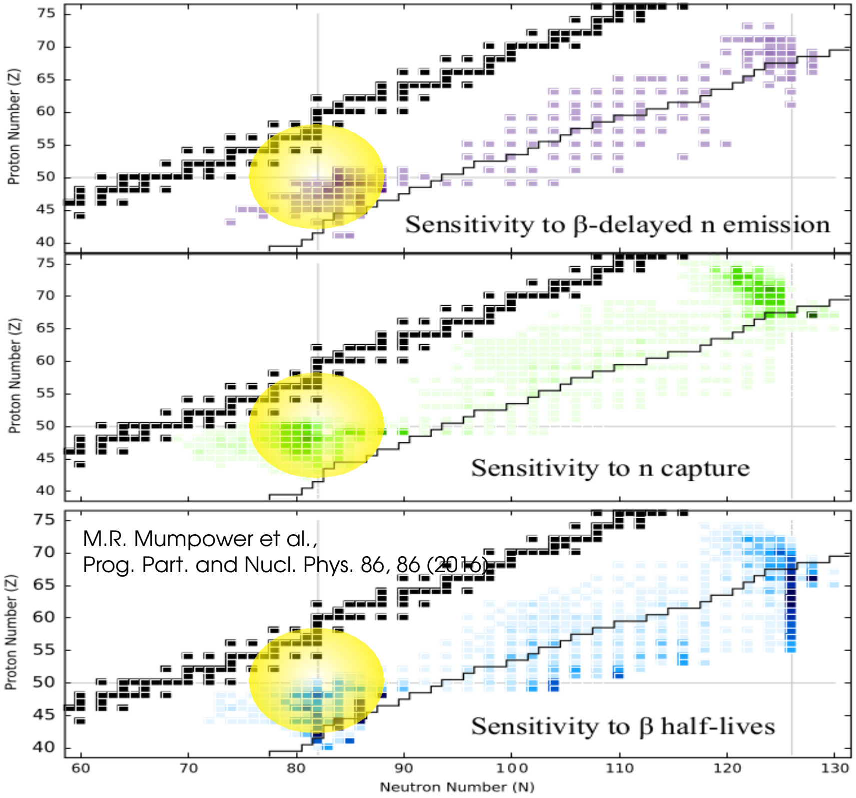
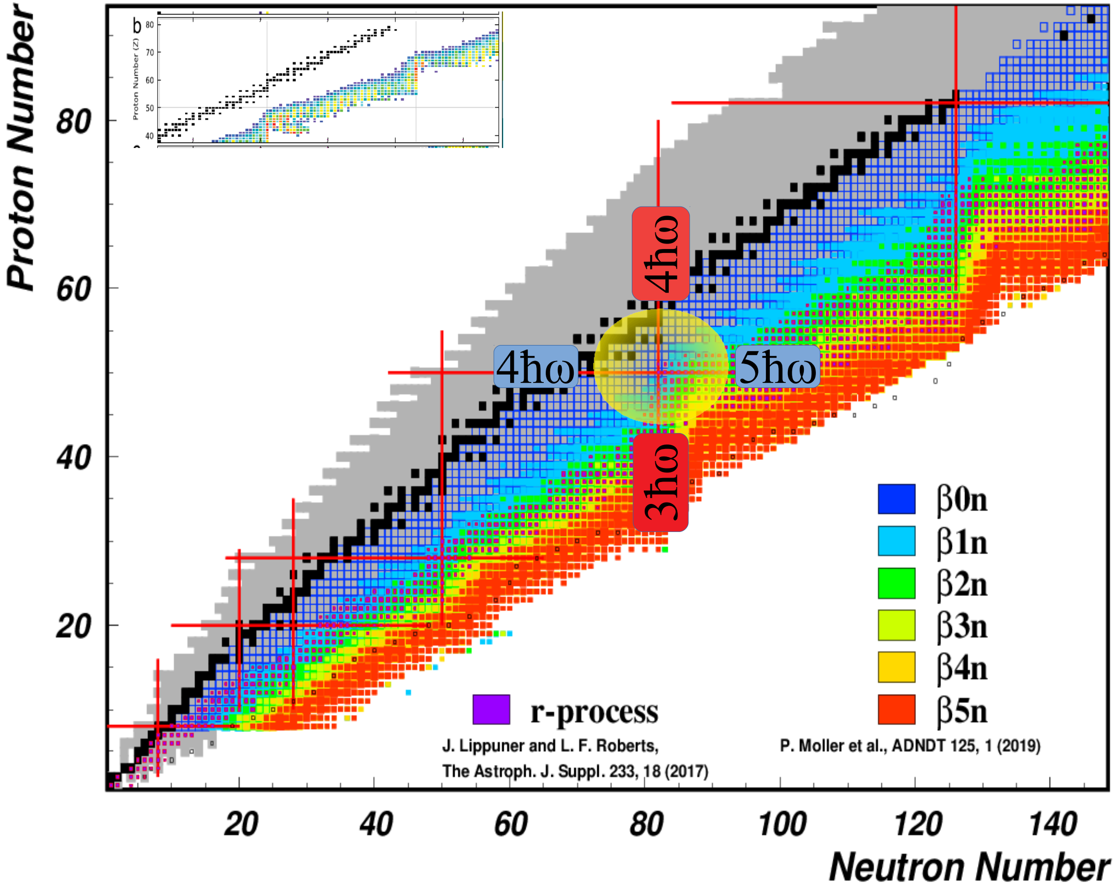


The ^{132}Sn region - nuclear structure meets astrophysics

Validate nuclear structure models with large pn assymetry.

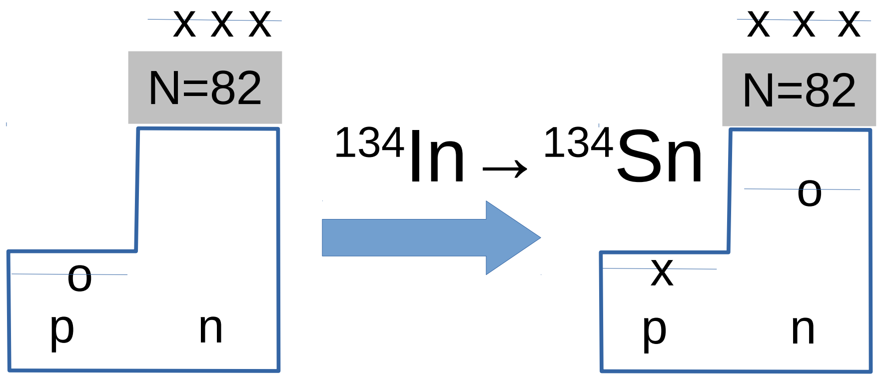


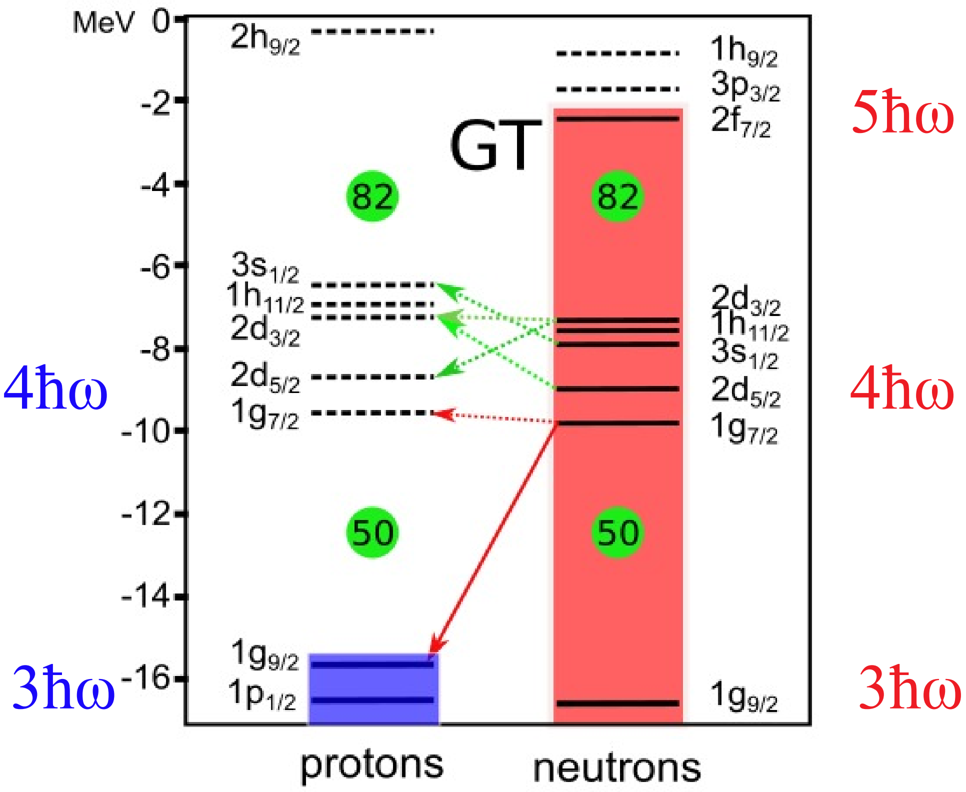


Beta decay near ^{132}Sn (Z<50)

Dominant transition

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

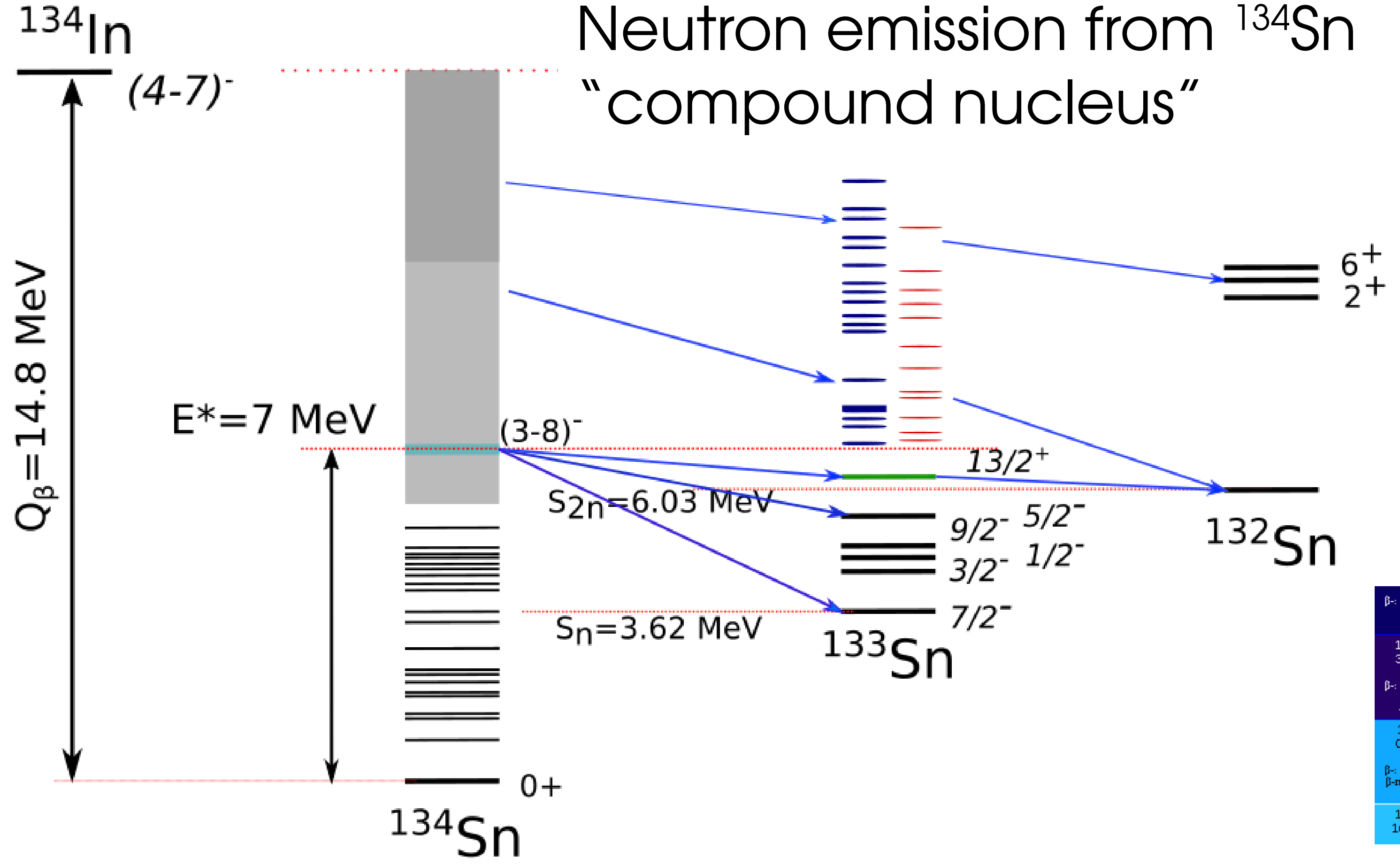




Gamow-Teller decays of N=82 isotopes near ^{132}Sn populates hole states in N=82 neutron core.

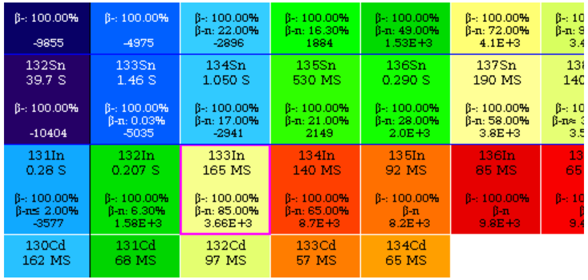
In the decay of ^{134}In excited states in ^{134}Sn, ^{133}Sn and ^{132}Sn are populated.

Neutron emission from ^{134}Sn "compound nucleus"



Large:

P_{1n}~0.8, P_{2n}~0.1

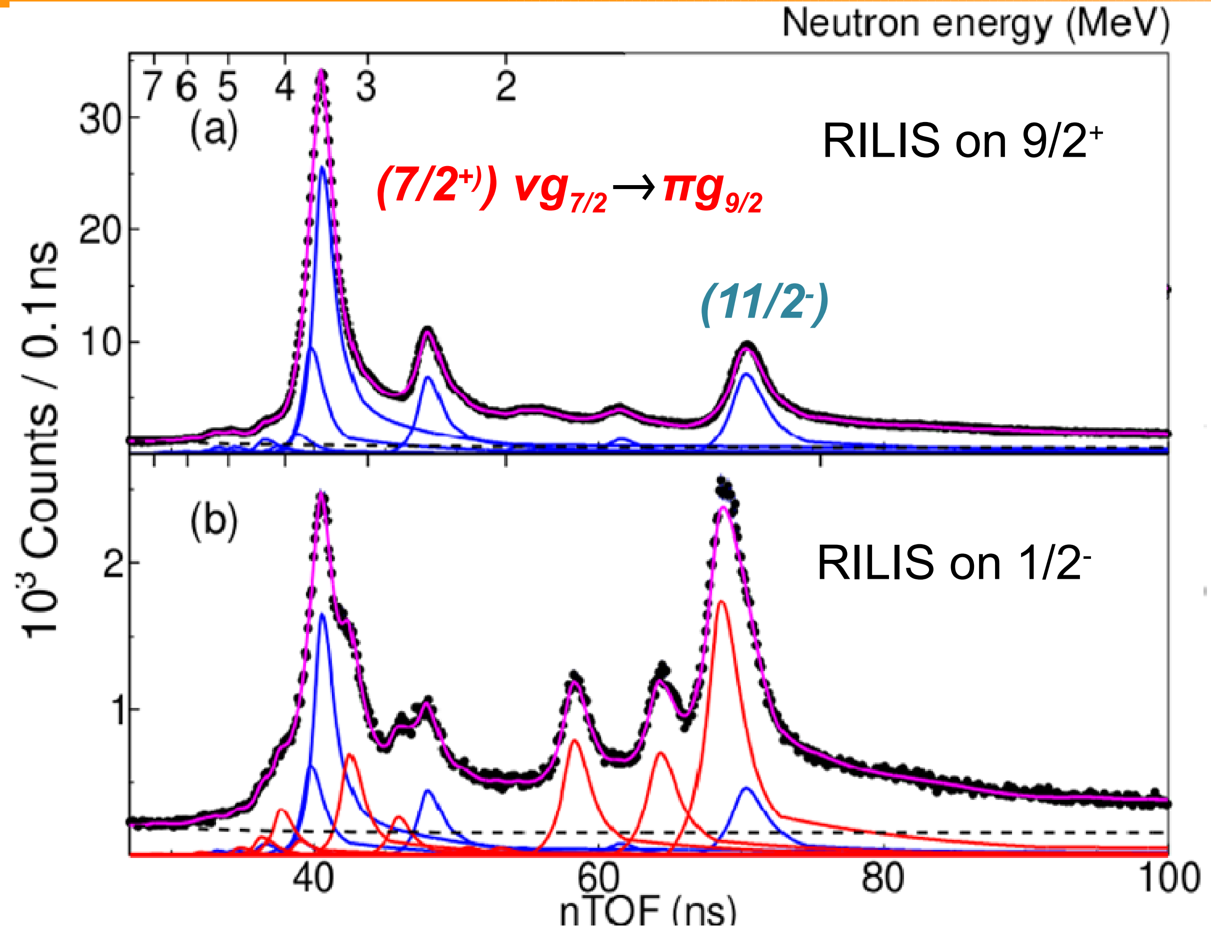


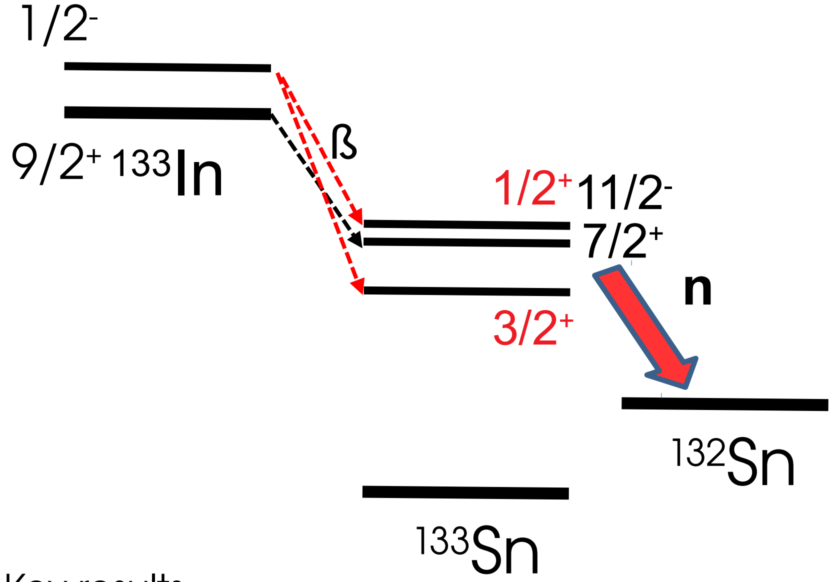
The four goals of the ^{134}In measurement

1. Measure the dominant GT transition and complete decay pattern (nuclear strucuture models, r-process)
2. 1n/2n emission and nn energy correlations (neutron emission model)
3. Search for neutron $i_{13/2}$ state in ^{133}Sn
4. Locate other (proton-core) excitation modes

The ^{133}In experiment

(Xu, Madurga, RG et al. manuscript to be submitted)





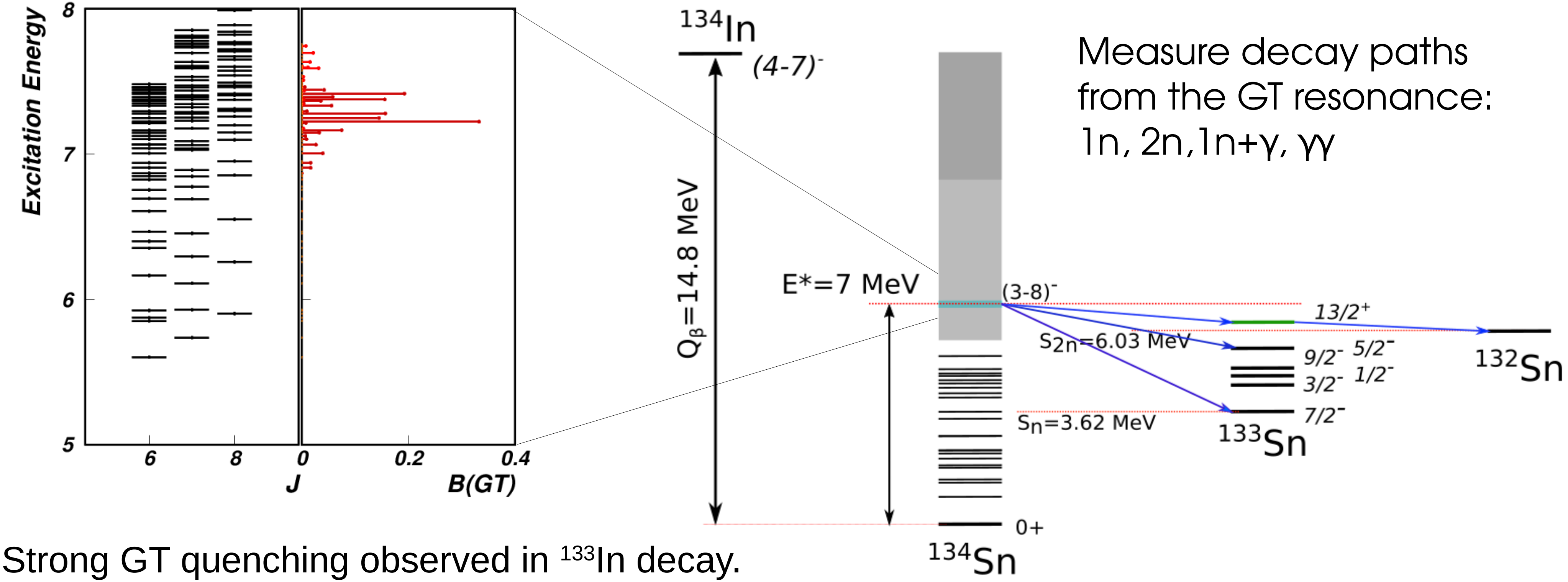
Key results:

- main GT transitions, large quenching
- neutron/gamma competition
- quantified role of FF
- large scale shell-model interpretation

$(\pi 3\hbar\omega, \nu 4\hbar\omega, \nu 5\hbar\omega)$

Predicted GT strength distribution for ^{134}In decay

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



Measure decay paths from the GT resonance: 1n, 2n, 1n+γ, γγ

Strong GT quenching observed in ^{133}In decay.

C. Yuan et al. Physics Letters B 762, 237 (2016).

jj46vmu (π3ħω,ν4ħω,ν5ħω)

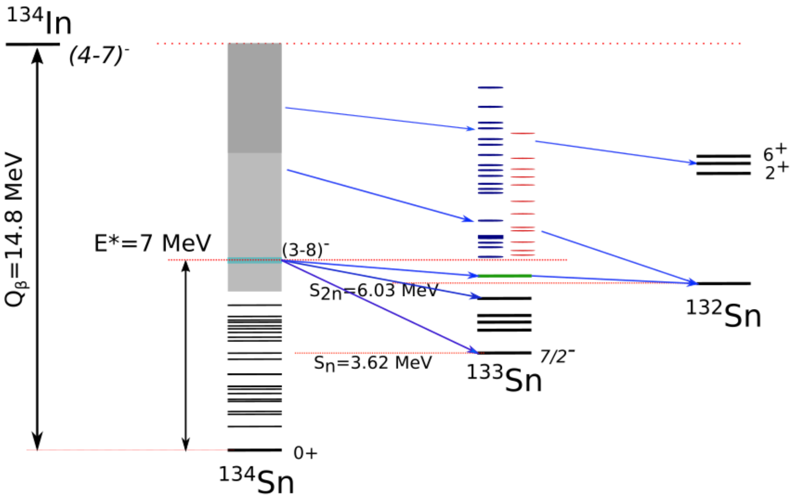
β2n spectroscopy of ^{134}In decay

β-: 100.00% -8425.0	β-: 100.00% -9855	β-: 100.00% -4975	β-: 100.00% β-n: 22.00% -2896	β-: 100.00% β-n: 16.30% 1884	β-: 100.00% β-n: 49.00% 1.53E+3	β-: 100.00% β-n: 72.00% 4.1E+3	β-: 100.00% β-n: 90.00% 3.4E+3
131Sn 56.0 S β-: 100.00% -8778	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	137Sn 190 MS β-: 100.00% β-n: 58.00% 3.8E+3	138Sn 140 MS β-: 100.00% β-n≈ 36.00% 3.5E+3
130In 0.29 S β-: 100.00% β-n: 0.93% -2.66E+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	136In 85 MS β-: 100.00% β-n 9.8E+3	137In 65 MS β-: 100.00% β-2n 9.4E+3
129Cd 154 MS β-: 100.0% β-n > 0.00% -2.30E+3	130Cd 162 MS β-: 100.00% β-n: 3.50% -3.11E+3	131Cd 68 MS β-: 100.00% β-n: 3.50% 1.48E+3	132Cd 97 MS β-: 100.00% β-n: 60.00% 3.48E+3	133Cd 57 MS β-: 100.00% β-2n 8.0E+3	134Cd 65 MS β-: 100.00% β-n 7.3E+3		

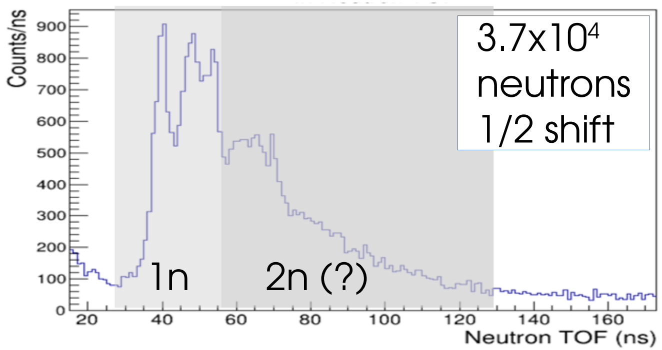
Large:

$Q_\beta - S_{2n} = 8.7$ MeV

$P_{2n} \sim 0.1$, $P_{1n} \sim 0.8$



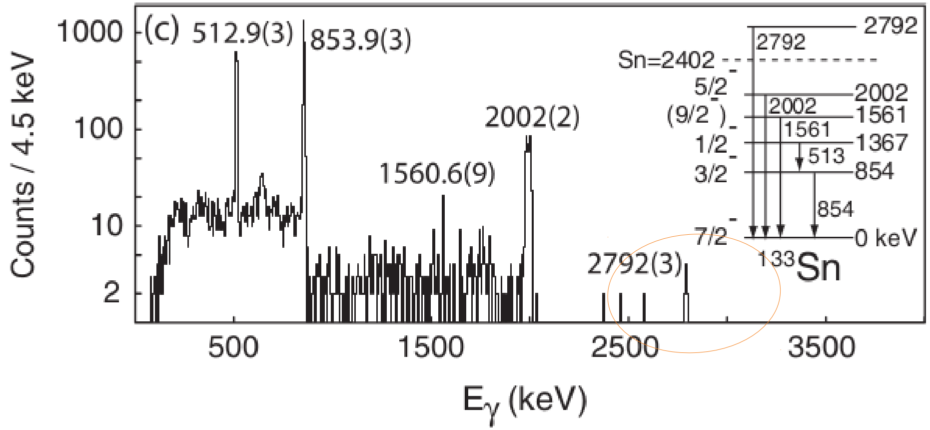
- 1n vs 2n competition
- excited states in ^{133}Sn (n-n)
- unbound states in ^{133}Sn previously studied
- decays to excited states in ^{132}Sn

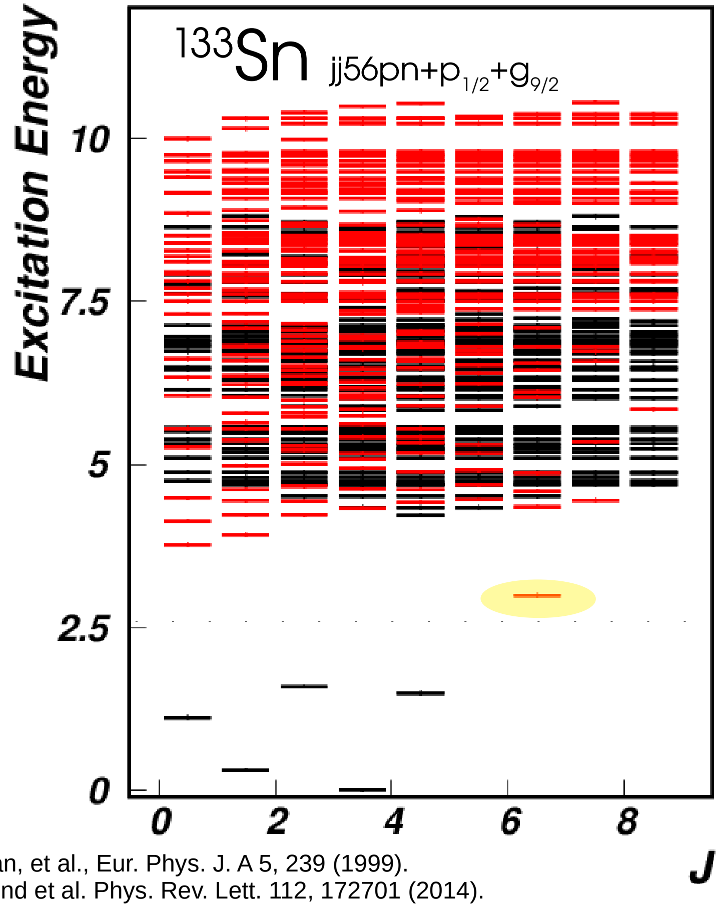


The $\nu i_{13/2}$ state in ^{133}Sn from β2n decay

- 2792 keV line observed in the ^{132}Sn(^{9}Be, ^{8}Be)^{133}Sn
- neutron unbound by about 400 keV
- expected to decay predominantly via neutron emission
- observed gamma ray (E3) not compatible
  with expected population of $i_{13/2}$ in neutron transfer reaction.

J. Allmond et al.



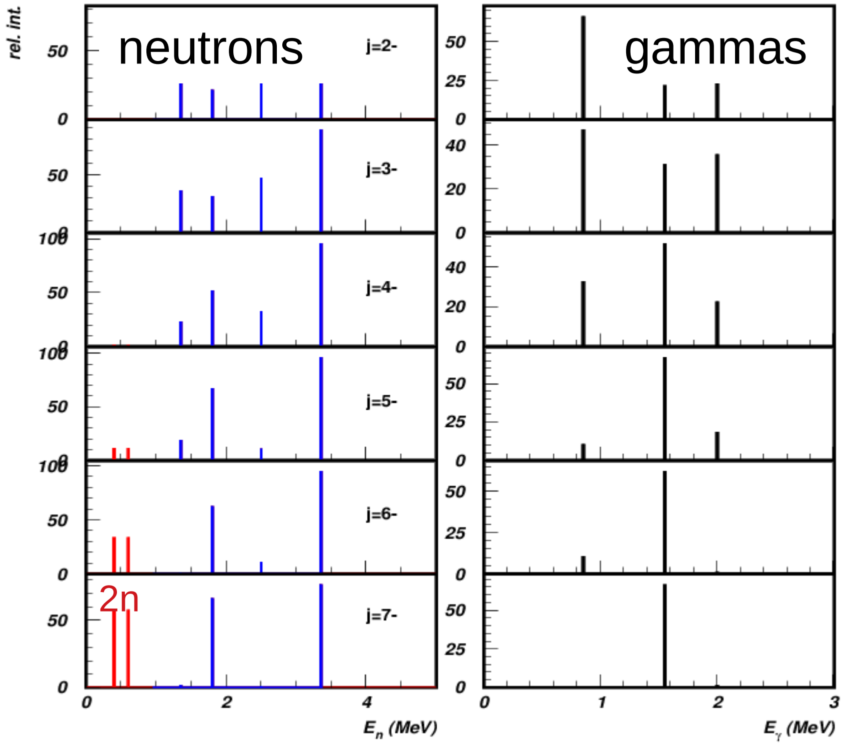


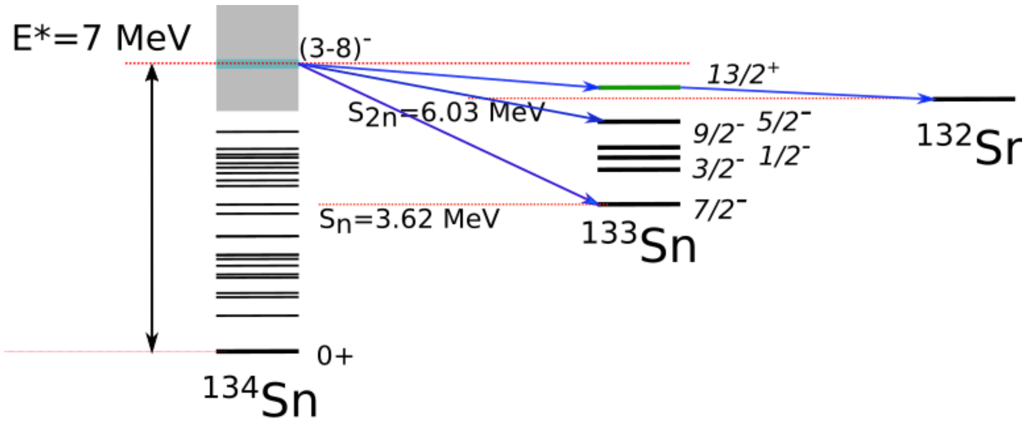
The 2792 keV line was not identified yet in beta decay of ^{134}In, either not real or weakly populated.

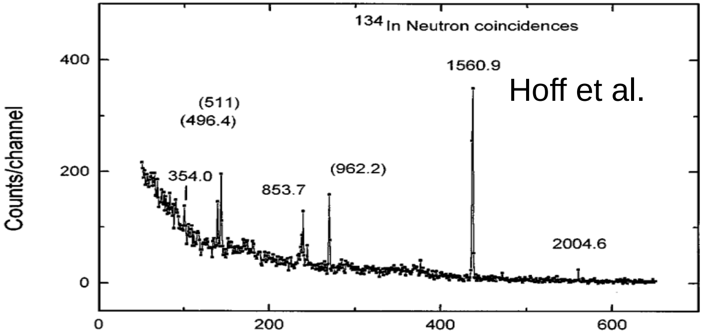
W. Urban, et al., Eur. Phys. J. A 5, 239 (1999).
J. Allmond et al. Phys. Rev. Lett. 112, 172701 (2014).
Y. Lei and H. Jiang, Phys. Rev. C 90, 047305 (2014)

Decay modes of E*=7 MeV state in ^{134}Sn as a function of spin

(coh3 code Kawano, Koning-Delaroche optical model)



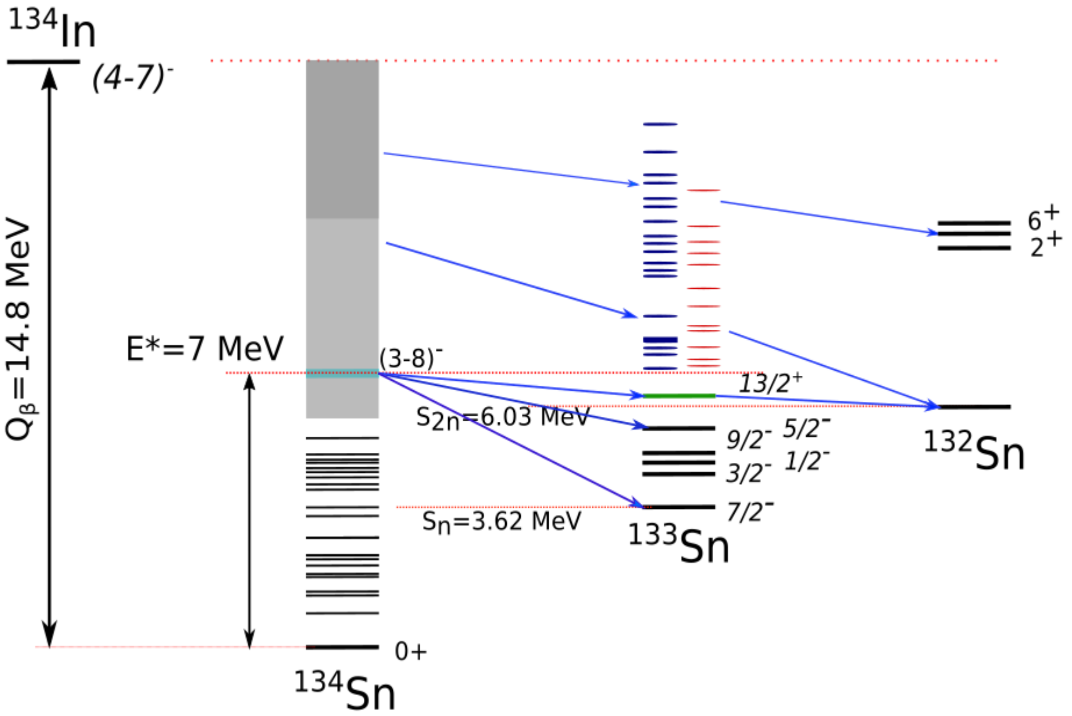


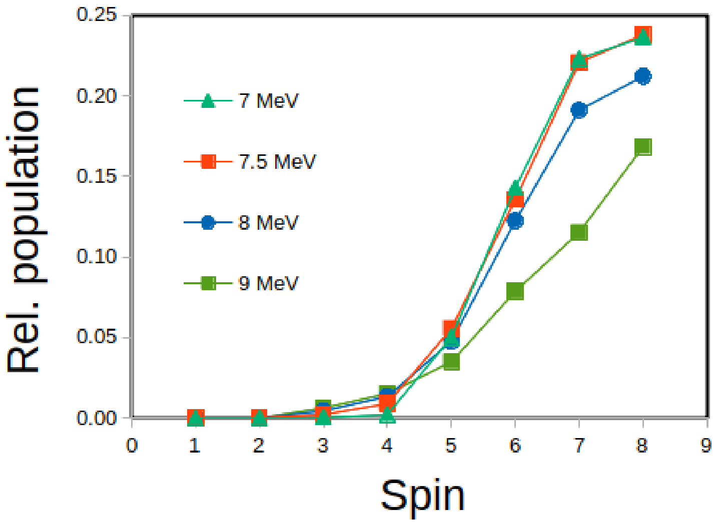


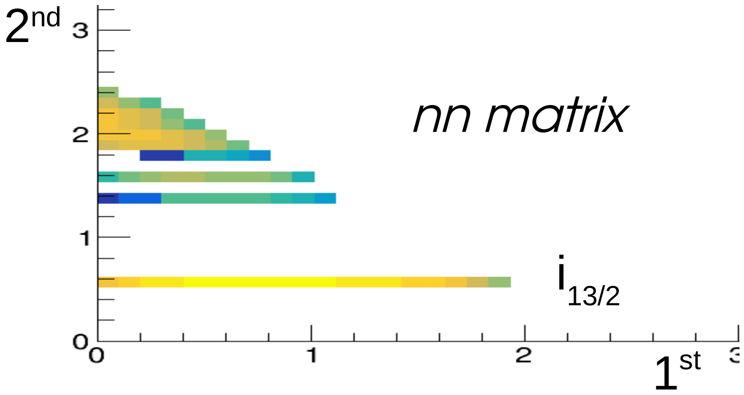
Large probability of single-neutron emission from 2n unbound states in ^{86,87}Ga

R. Yokoyama et al., Phys. Rev C 100(3), 031302(R) (2019).

Population of $i_{13/2}$ state in ^{133}Sn as a function of the spin of the neutron emitting state in ^{134}Sn



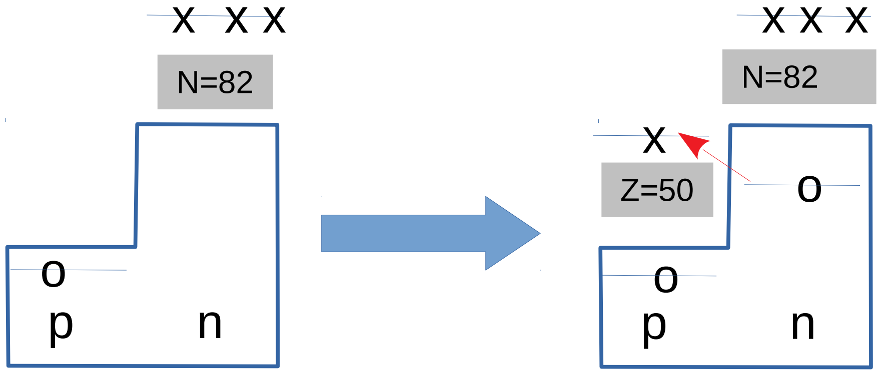




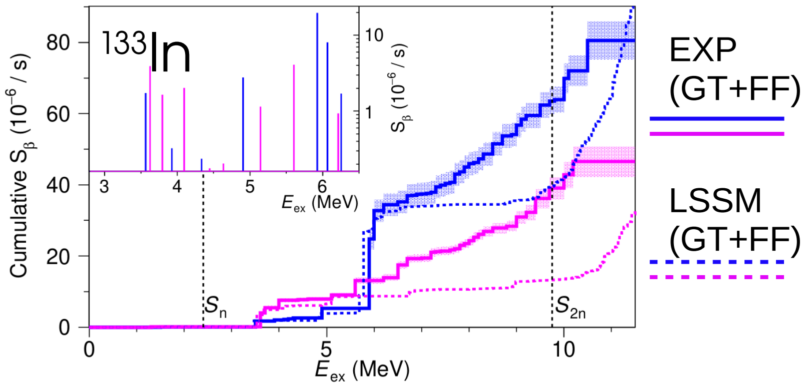
Prevalent population of 9/2$^-$ state in ^{133}Sn and the population of 6+ state in ^{132}Sn suggests) the high-spin of ^{134}In (M. Piersa et al.)

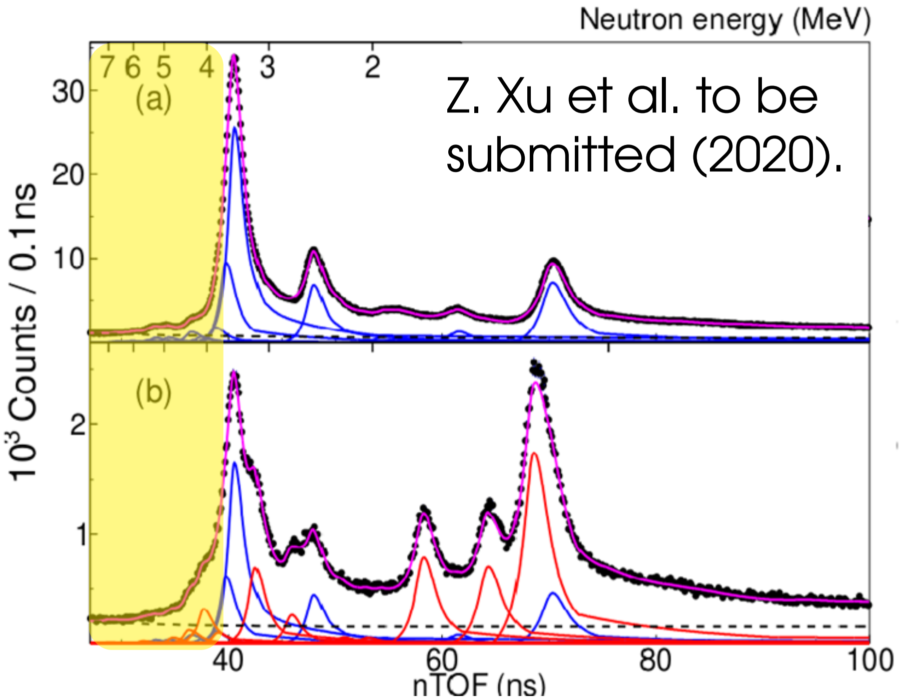
Population of highly excited states in ^{134}Sn proton-core or other modes of excitations ?

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



Large discrepancy !

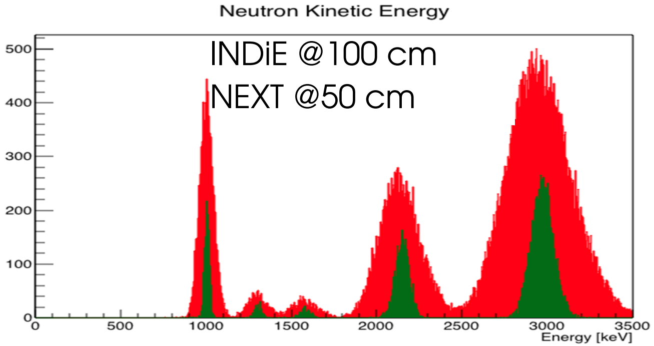


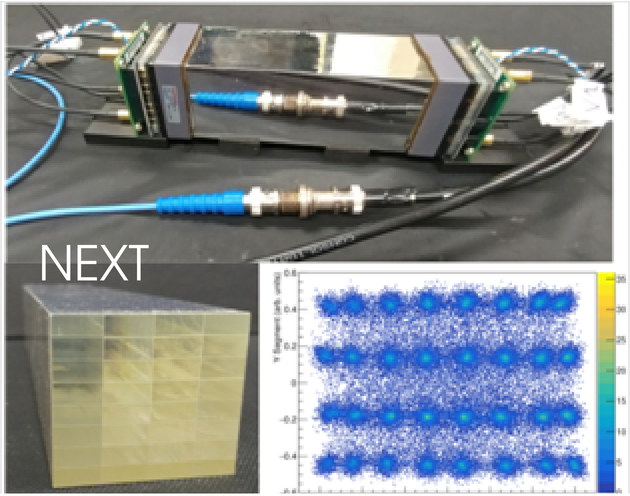


Z. Xu et al. to be submitted (2020).

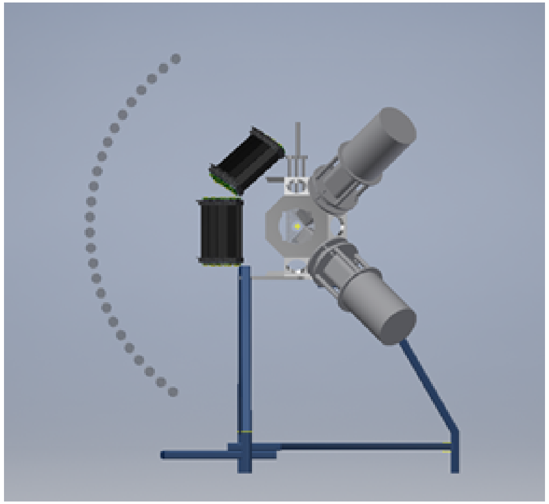
also: $^{132}In \rightarrow ^{132}Sn$

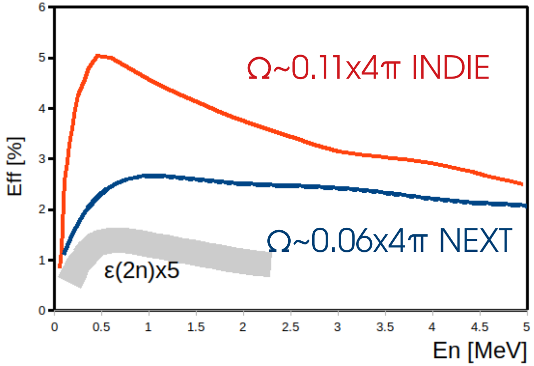
INDiE and NEXT arrays at IDS

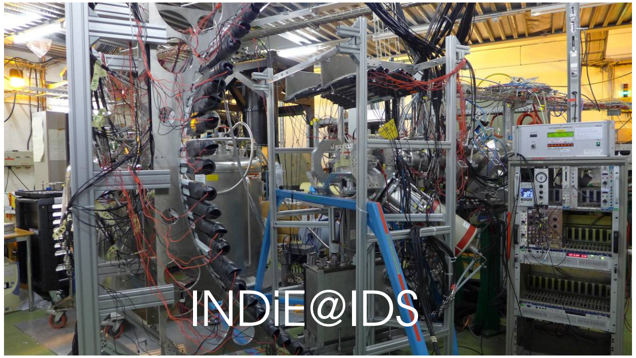




J. Heideman et al.
Nuclear Instruments and Methods A, 946 (2019) 162528.



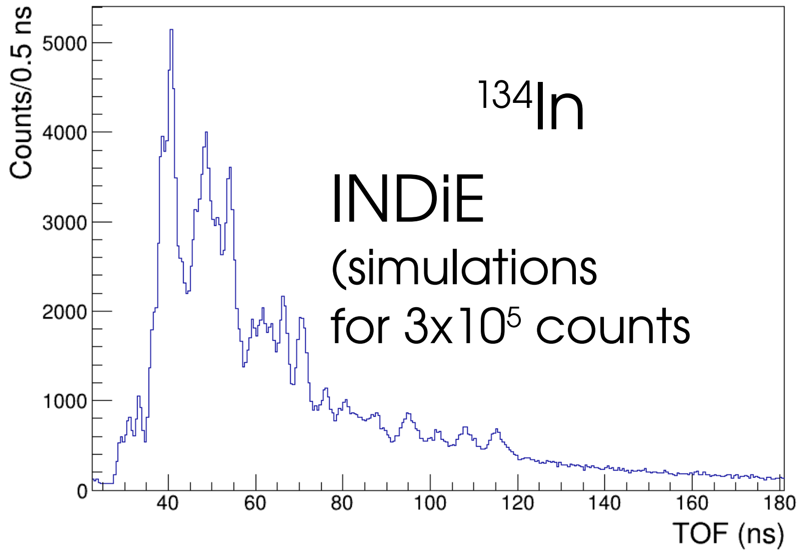




Beam time request

Collect statistics sufficient to construct nn and nγ cascades.

15 shifts to collect ~1x10^6 neutrons ^{134}In (INDiE)
2 shifts to collect ~0.5x10^6 neutrons from ^{132}In
During the 15 shifts we expect to collect about 15x10^3 of two-neutron events.



IDS with RILIS uniquely positioned to perform the pioneering (and high statistics)

2n spectroscopy of ^{134}In decay

Table 1: Expected neutron rates. These calculations are done for 2 uC PS Booster beam and 50% transmission efficiency to IDS (n.c. = neutron converter)

	P_{1n} (%)	Yield (ion/µC)	IDSND Eff	Neutrons (1/h)	Shifts	Target	Source
^{132}In	6.3%	8000	0.04	4.0 10^4	2	UC_X+n.c.	Hot Ta line and cavity + RILIS
^{134}In	80%	100	0.04	8.1 10^3	15	UC_X+n.c.	Hot Ta line and cavity + RILIS
^{17}N	95.1%	100	0.04	1.0 10^5	1	CaO	Hot Ta line and cavity

INTC 64 June 2020: Technical advisory committee recommendations:

Beam intensity/purity, targets-ion sources
The isotopes have been delivered previously. №te that Iodine will not be ionised, the main contaminant will be Cs.
17N could potentially be also delivered from a UC target with VD7 ion source which may facilitate scheduling.
General Comments
The beam request entails two different targets and ion sources, although this has been possible in the past it is difficult to schedule. Is there an alternative calibration isotope for VANDLE from a "standard" UC target/ion source?
TAC recommendation
The TAC does not see any serious issues with this proposal. ***The main difficulty would be in scheduling two targets to allow for the calibration run.*** If a plan B could be found it would make ease the scheduling.

Response:
^{134m}Cs contamination is suppressed by the tape cycle and by the gate on the beta plastic scintillator but is generally not desired for the 2n measurement.

The ^{17}N calibration run can be substituted by the ^{49}K calibration run.

The ^{49}K spectrum is more complex but has been utilized in the past and large yields are expected from the standard UCx source used for this experiment.