Shape coexistence in Sn isotopes around A=110

Young GAMMA Meeting - Asiago 2024

Giacomo Corbari

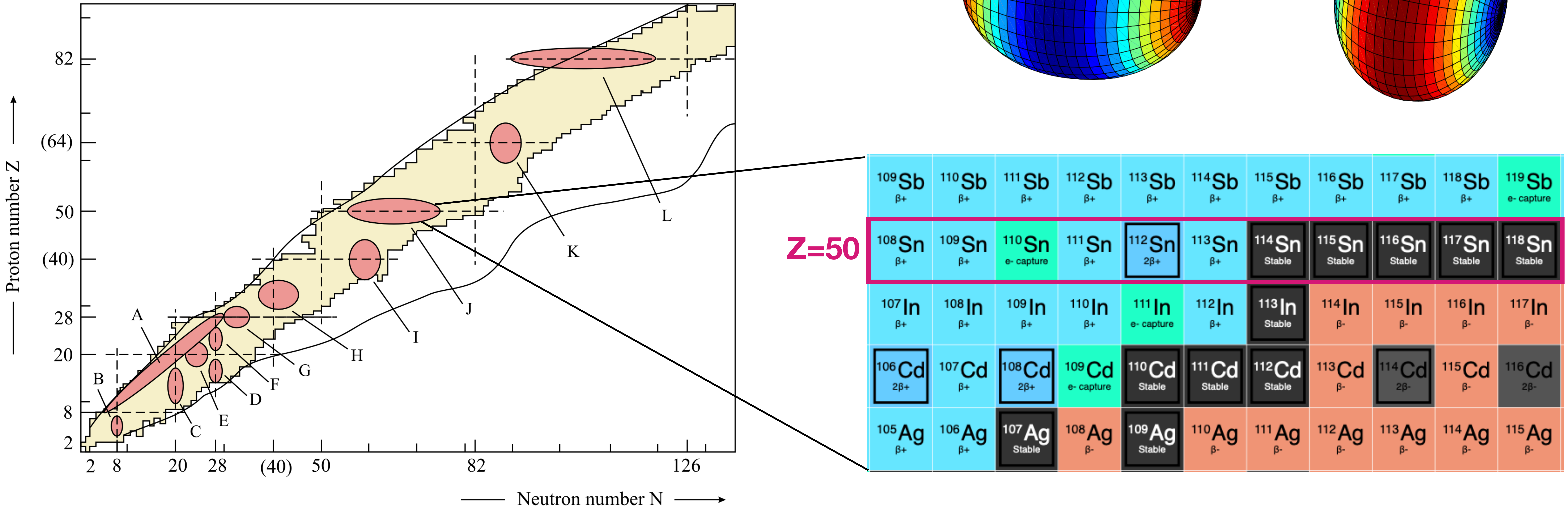
Università degli Studi di Milano - INFN Milano

INFN

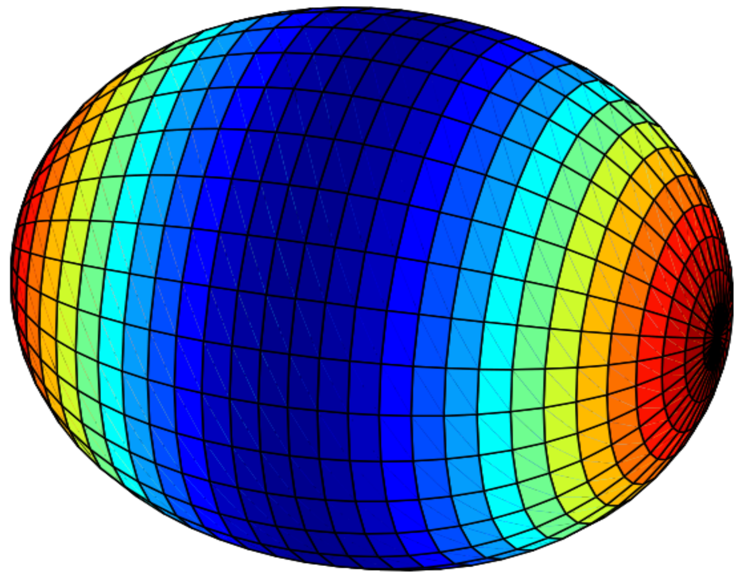
UNIVERSITÀ DEGLI STUDI DI MILANO

Shape coexistence

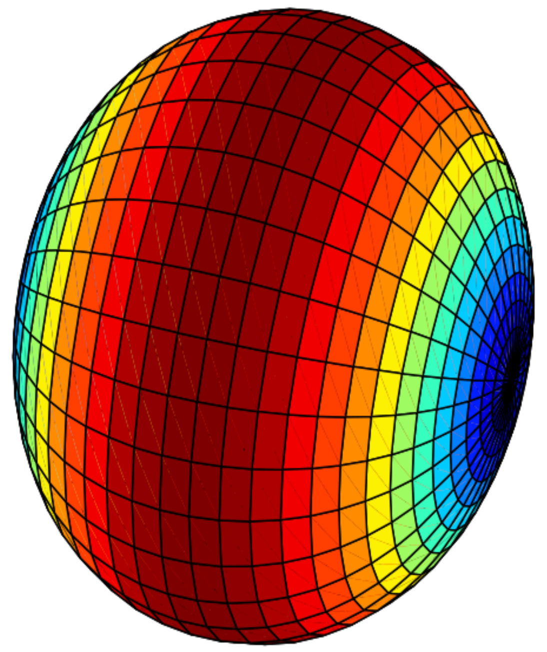
Quadrupole deformations predicted and observed in excited states of nuclei around the A~110 region



Prolate



Oblate

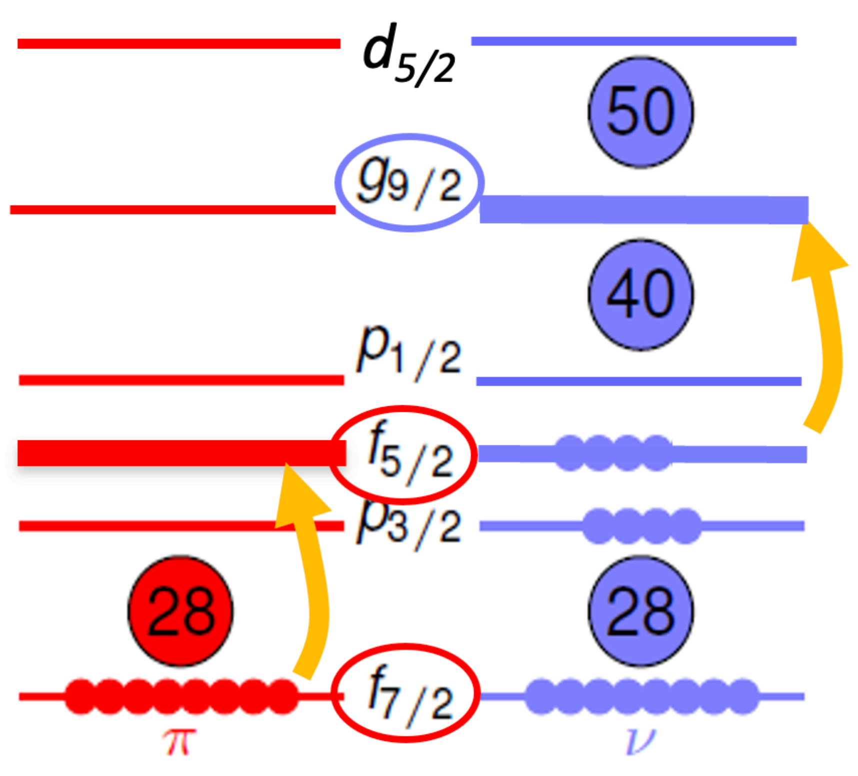


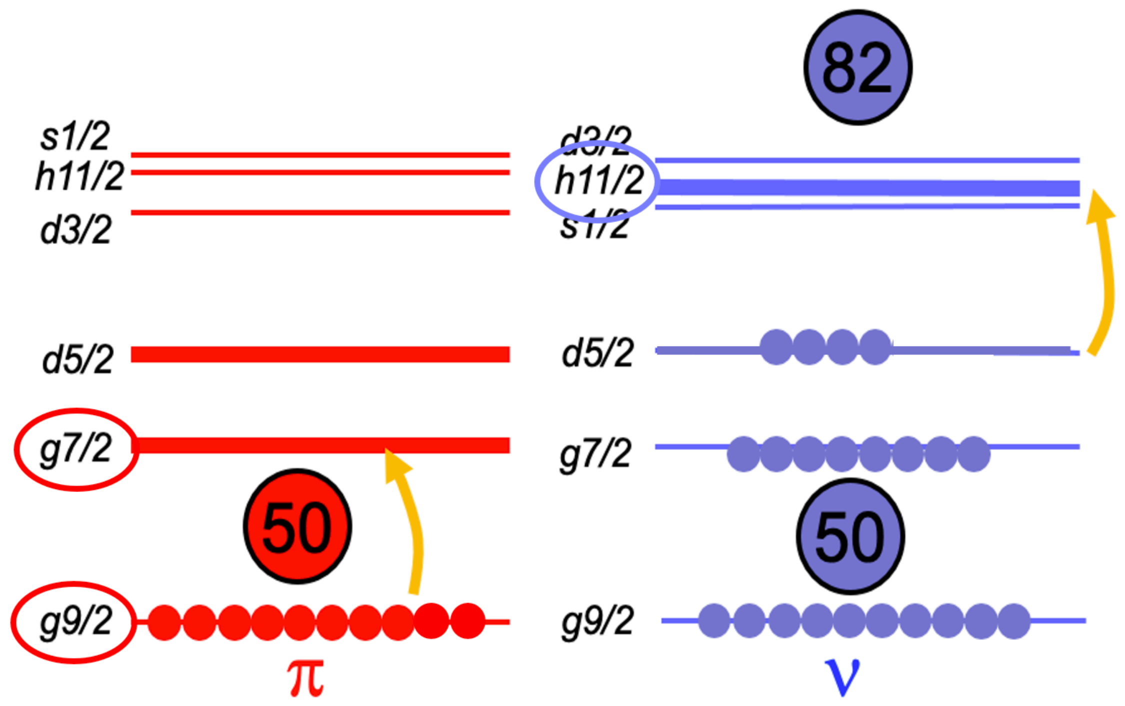
K. Heyde and J. Wood, Rev. Mod. Phys. 83, 1467 (2011)

B. Lu, J. Zhao, E. Zhao, S. Zhou, EPJ Web of Conferences 38 05003 (2012)

Origin of the 0^+ excitations

Shape coexistence at Z=50

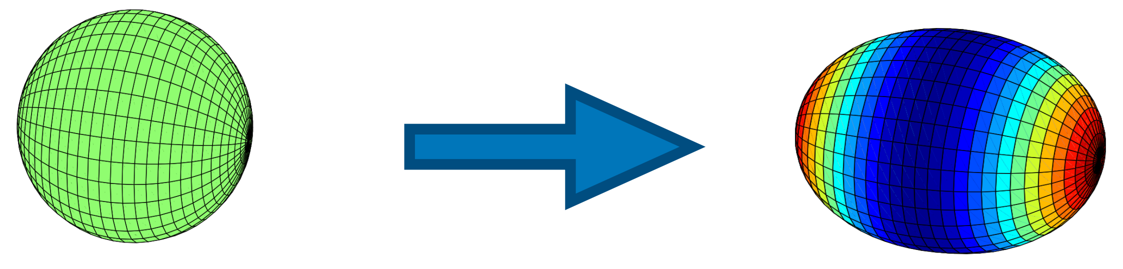




^{64}Ni ^{112}Sn

<u>Expected similar scenario to Ni</u>

Spontaneus simmetry breaking

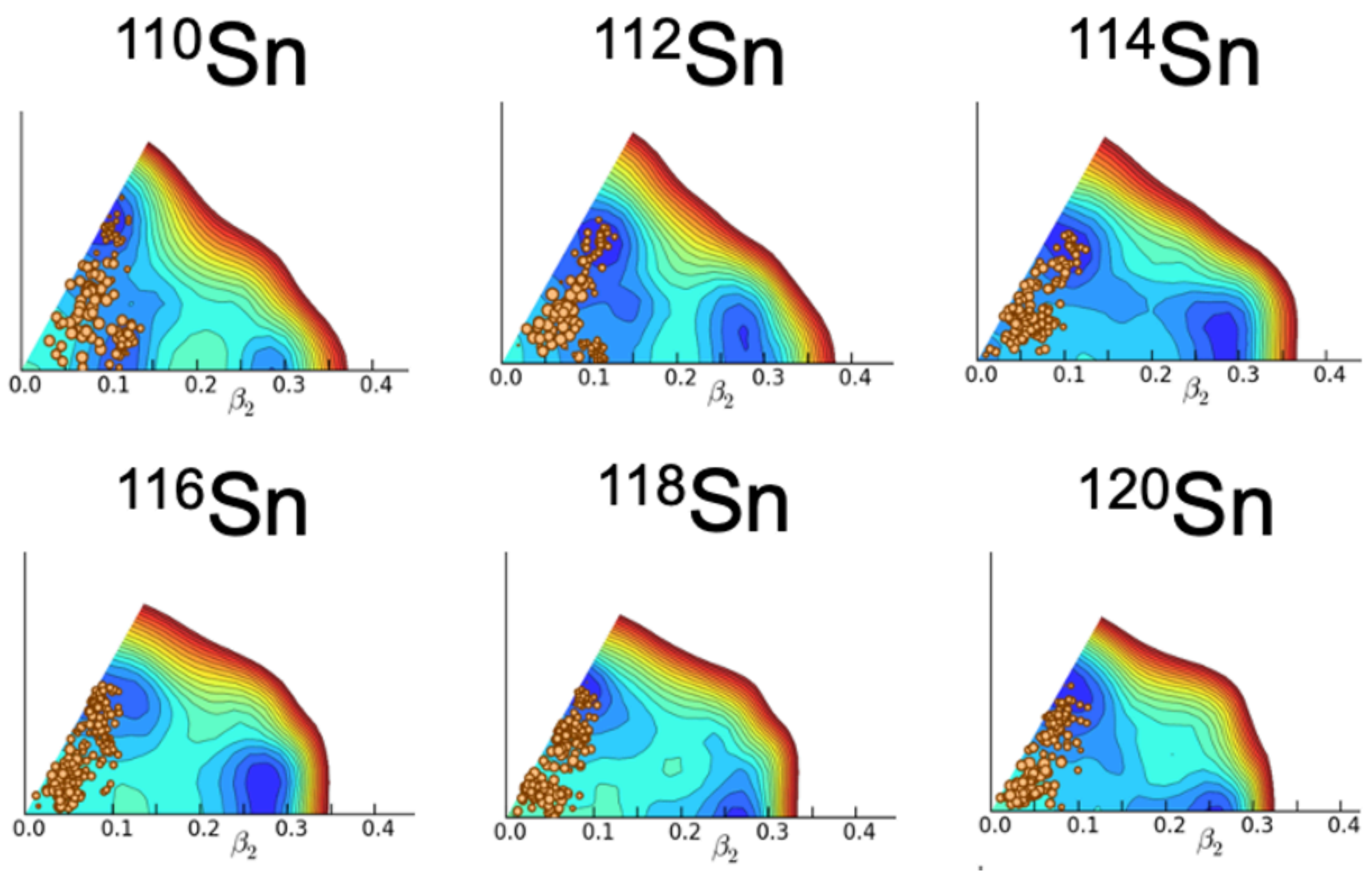


Induced by proton-neutron interaction

Hartree-Fock-Bogoliubov PES

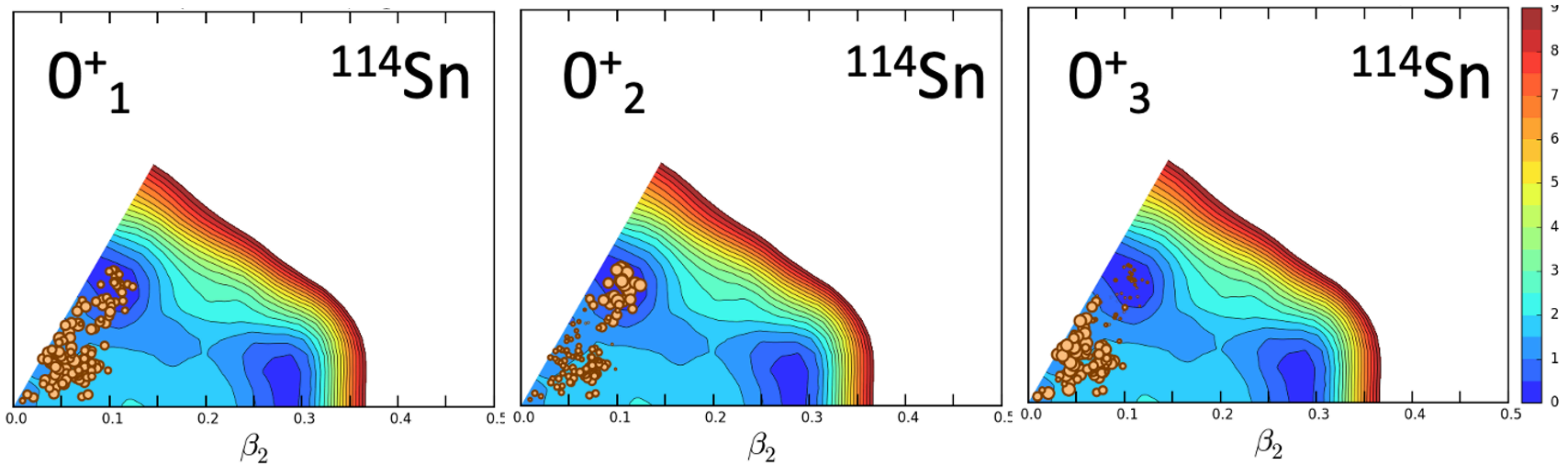
T. Togashi et al., Phys. Rev. Lett. 121, 062501 (2018).

T. Otzuka, Y. Tsunoda, to be published.

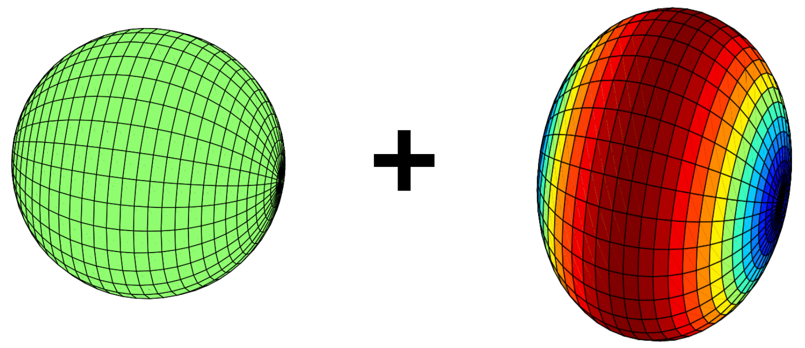


Well-separated prolate minimum appearing from ^{112}Sn up to ^{118}Sn

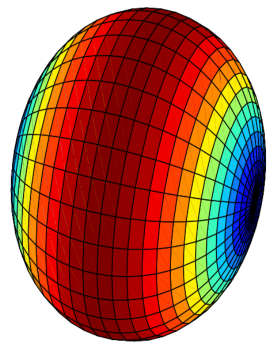
A study case: ^{114}Sn



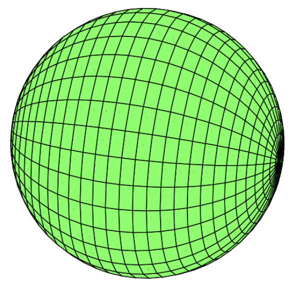
Spherical + oblate g.s.



Oblate 0^+_2



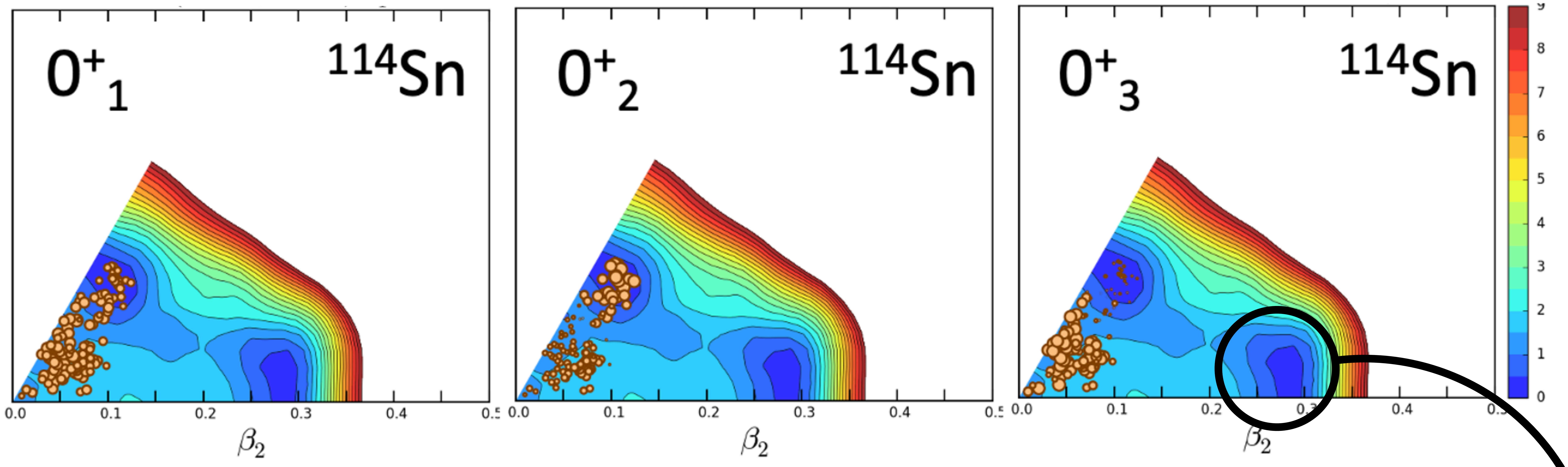
Spherical 0^+_3



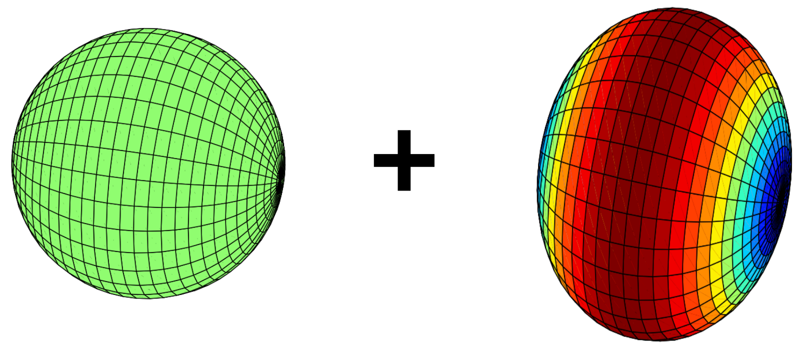
T. Otzuka, Y. Tsunoda, to be published.

T. Togashi et al., Phys. Rev. Lett. 121, 062501 (2018).

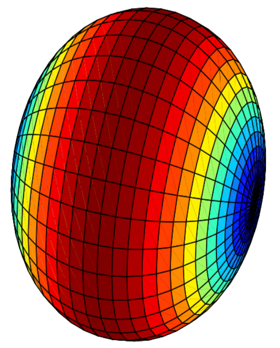
A study case: ^{114}Sn



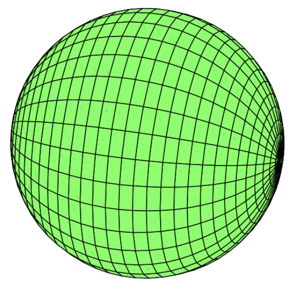
Spherical + oblate g.s.



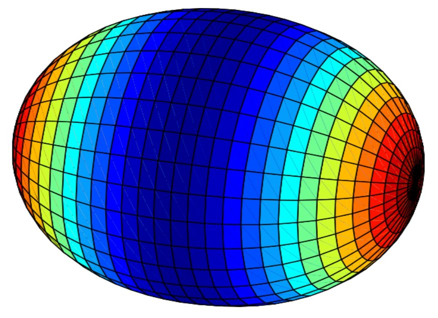
Oblate 0^+_2



Spherical 0^+_3



Prolate 0^+_4 ??



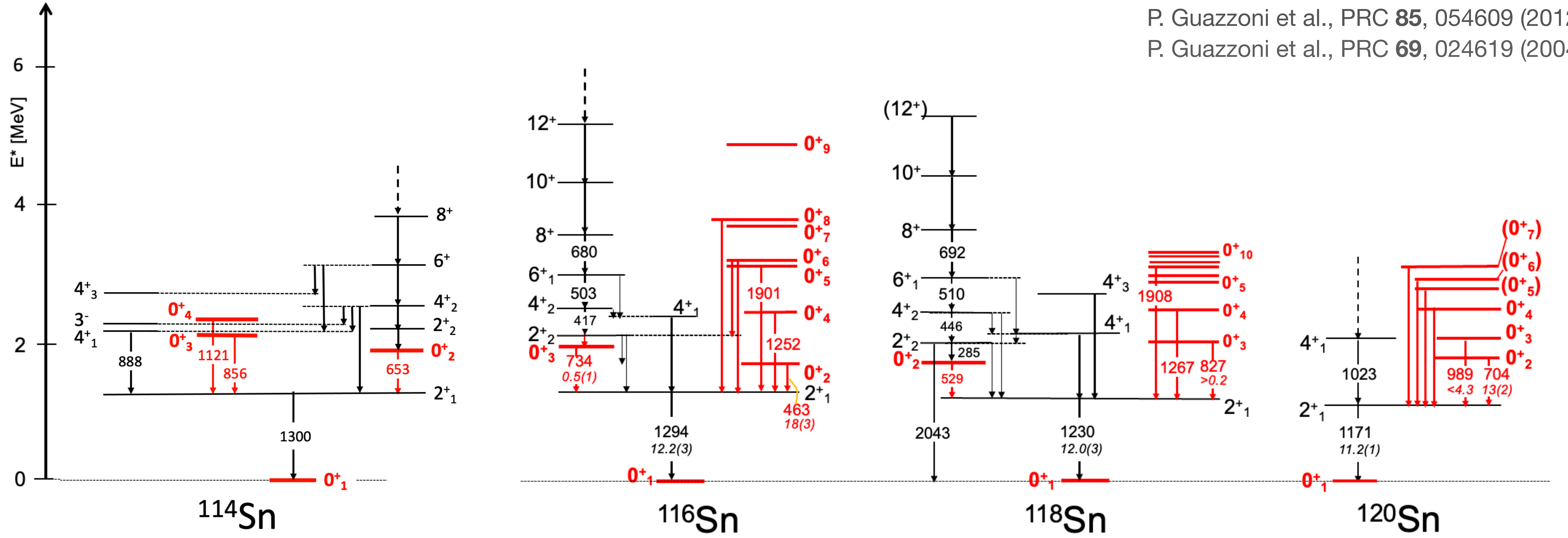
T. Otzuka, Y. Tsunoda, to be published.

T. Togashi et al., Phys. Rev. Lett. 121, 062501 (2018).

How to probe shape coexistence?

Several 0+ states observed in this region!

R. L. Auble et al., PRC **6**, 2223 (1972)
P. Guazzoni et al., PRC **74**, 054605 (2006)
P. Guazzoni et al., PRC **85**, 054609 (2012)
P. Guazzoni et al., PRC **69**, 024619 (2004)



Few lifetimes known! → Experimental investigation needed

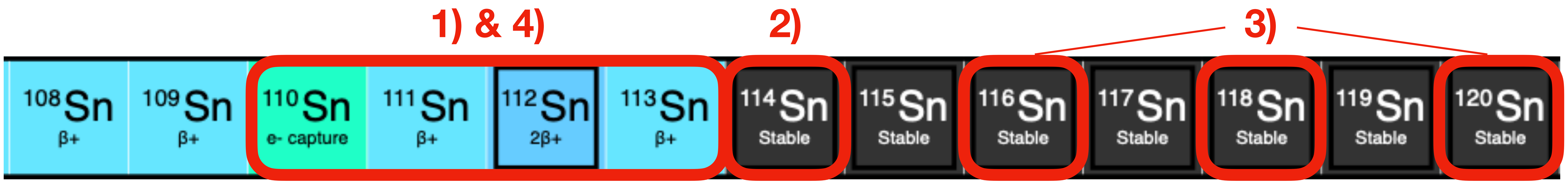
A series of complementary experiments

Experiment at LNL with AGATA-PRISMA on Sn isotopes near A=110

1) Lifetime measurements of 0^+ states in ^{112}Sn - July 2022

Experiments at IFIN-HH on $^{112-120}$Sn at sub-barrier energies

2) Lifetime measurements of 0^+ states in ^{114}Sn - October 2022
3) Low-spin spectroscopy of $^{116-118-120}$Sn with different probes - October 2023
4) Lifetime measurements of ^{111,112,113}Sn - November 2023



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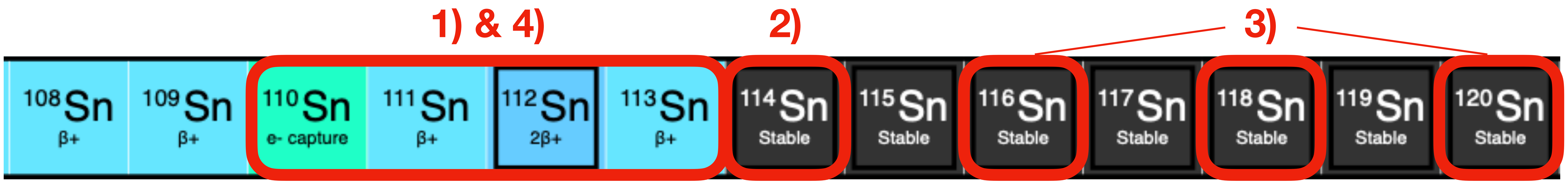
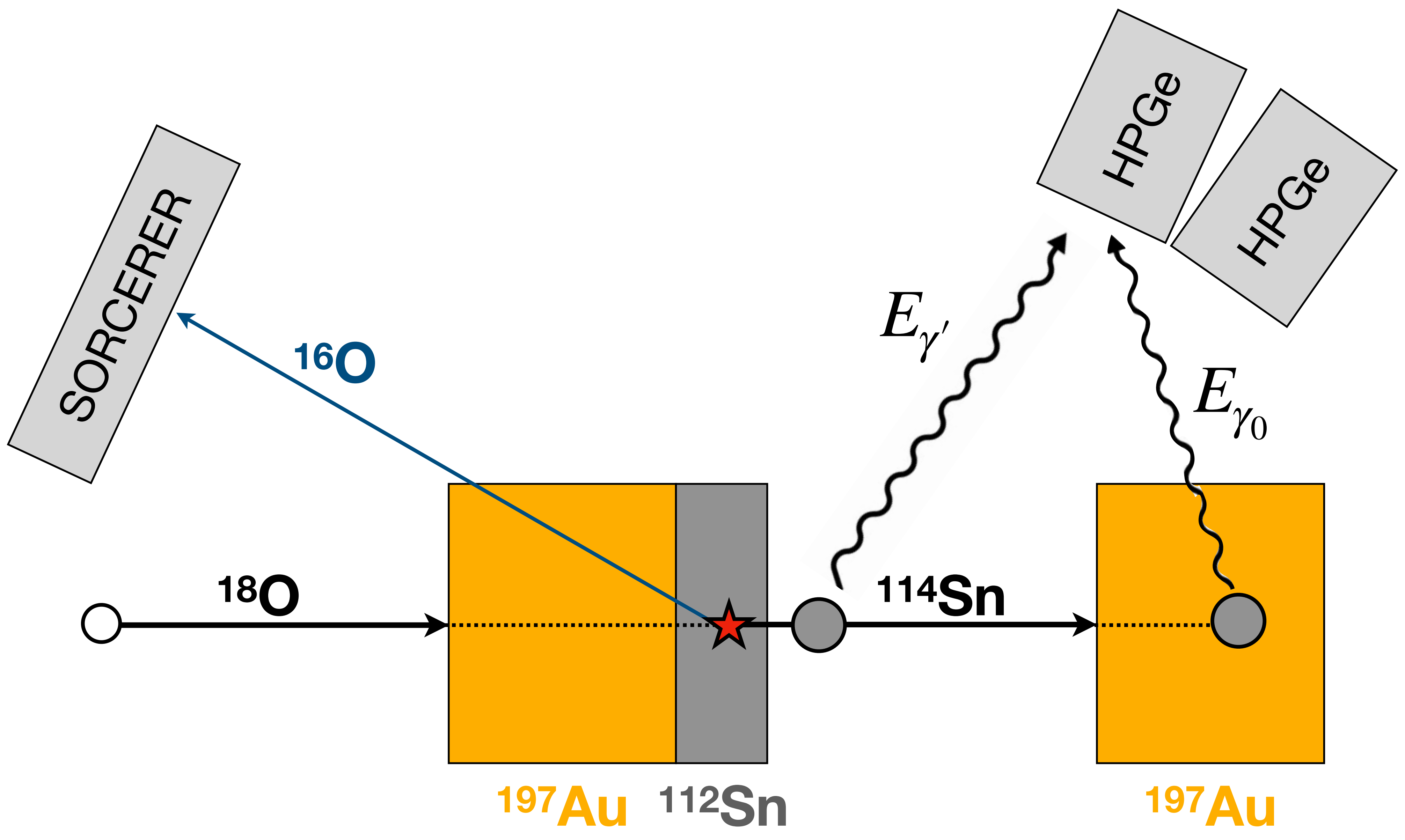


ROSPHERE + Plunger @ IFIN
^{114}Sn - 2n transfer

ROSPHERE-SORCERER @ IFIN

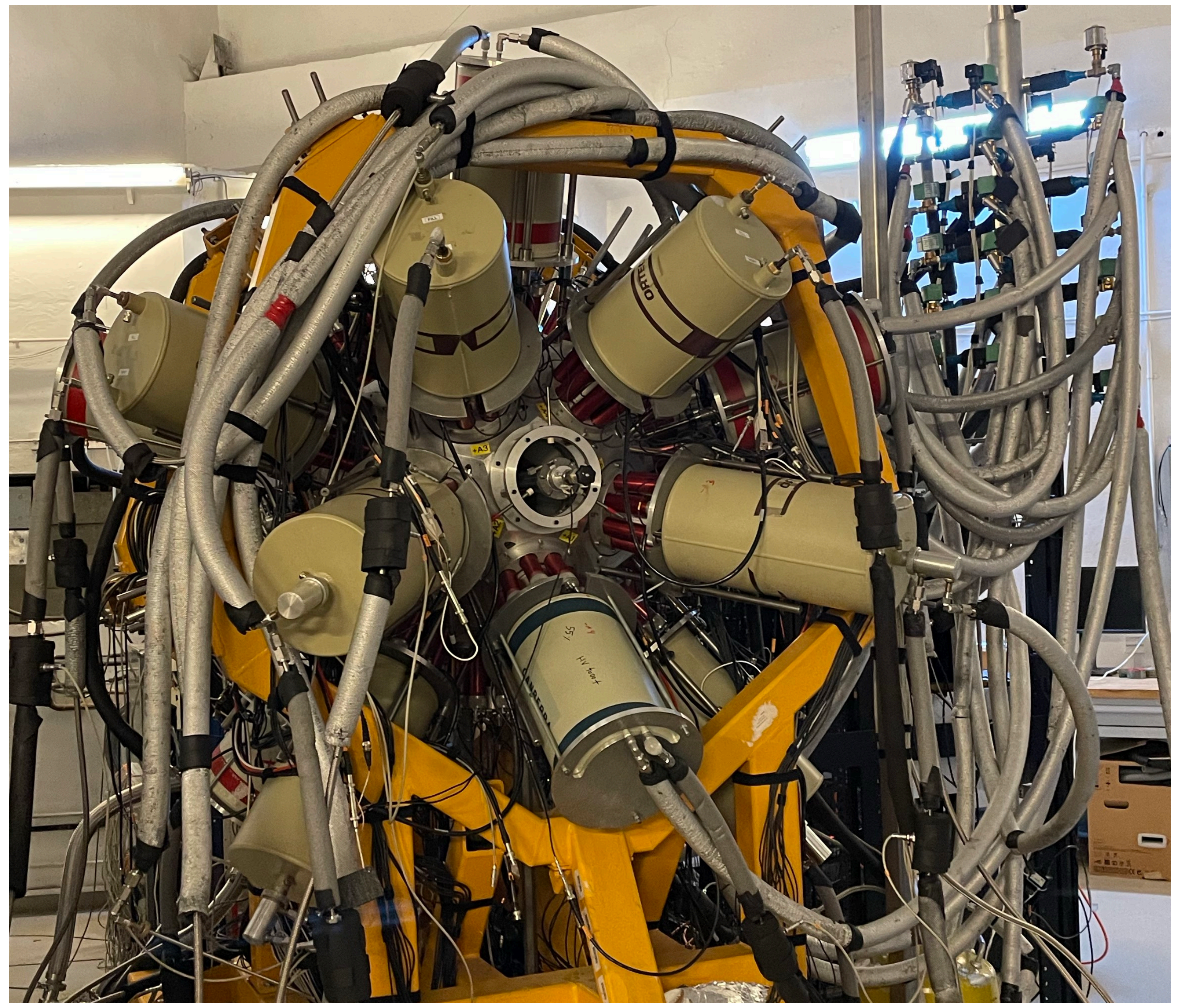
Experiment in November 2022



$$^{112}Sn(^{18}O,^{16}O)^{114}Sn$$

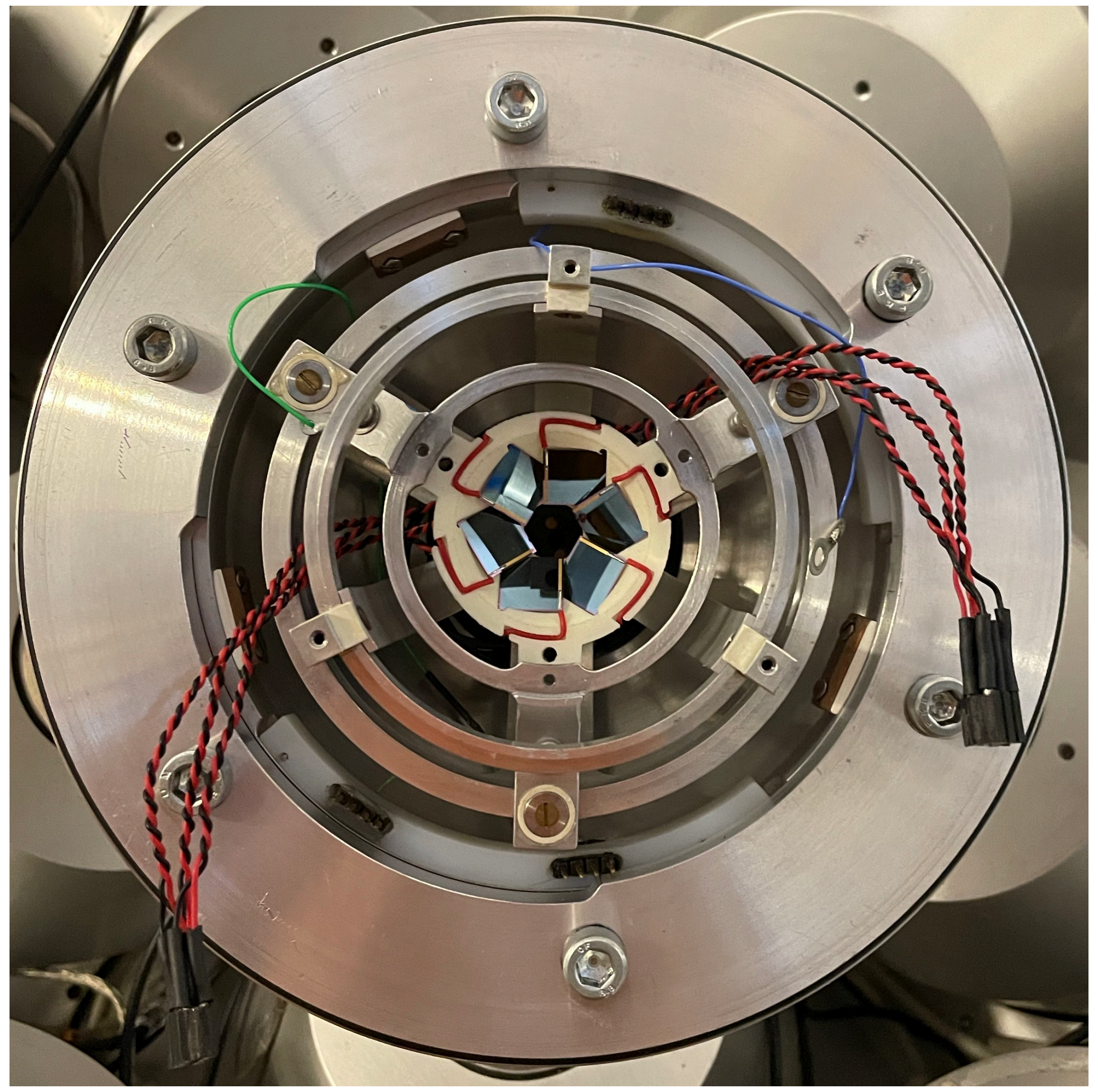
2n transfer reaction at 59 MeV

ROSPHERE



- 20 HPGe + BGO
- 5 CeBr scintillators

SORCERER



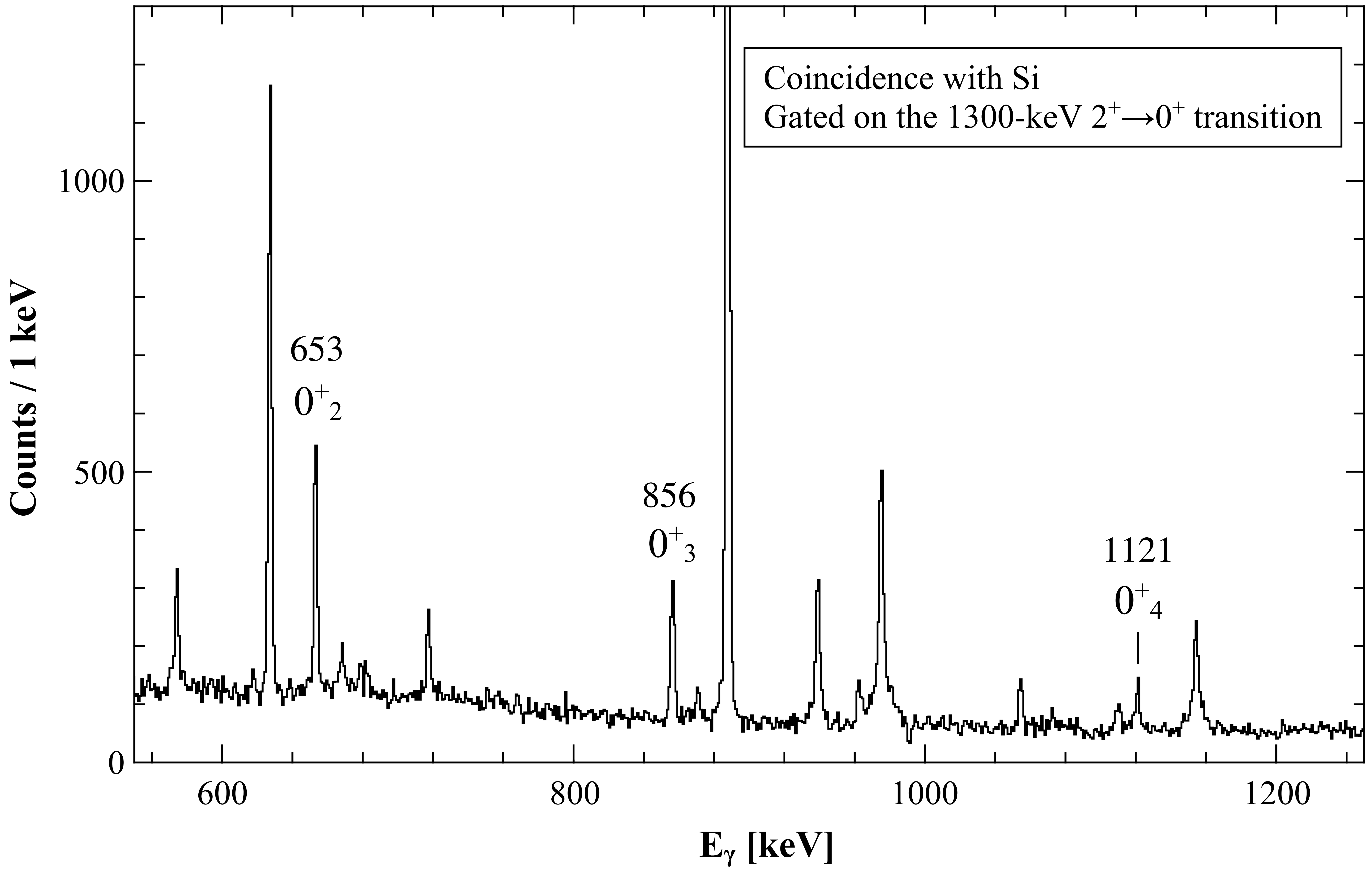
- 6 Si solar cells

D. Bucurescu et al., NIM A 837 (2016) 1–10

T. Beck, C. Costache, R. Lică et al., NIM A 951 (2020) 163090

ROSPHERE @ IFIN: ^{114}Sn thick target

3-days test experiment in 2021 with a thick 10 mg/cm^2 ^{112}Sn target

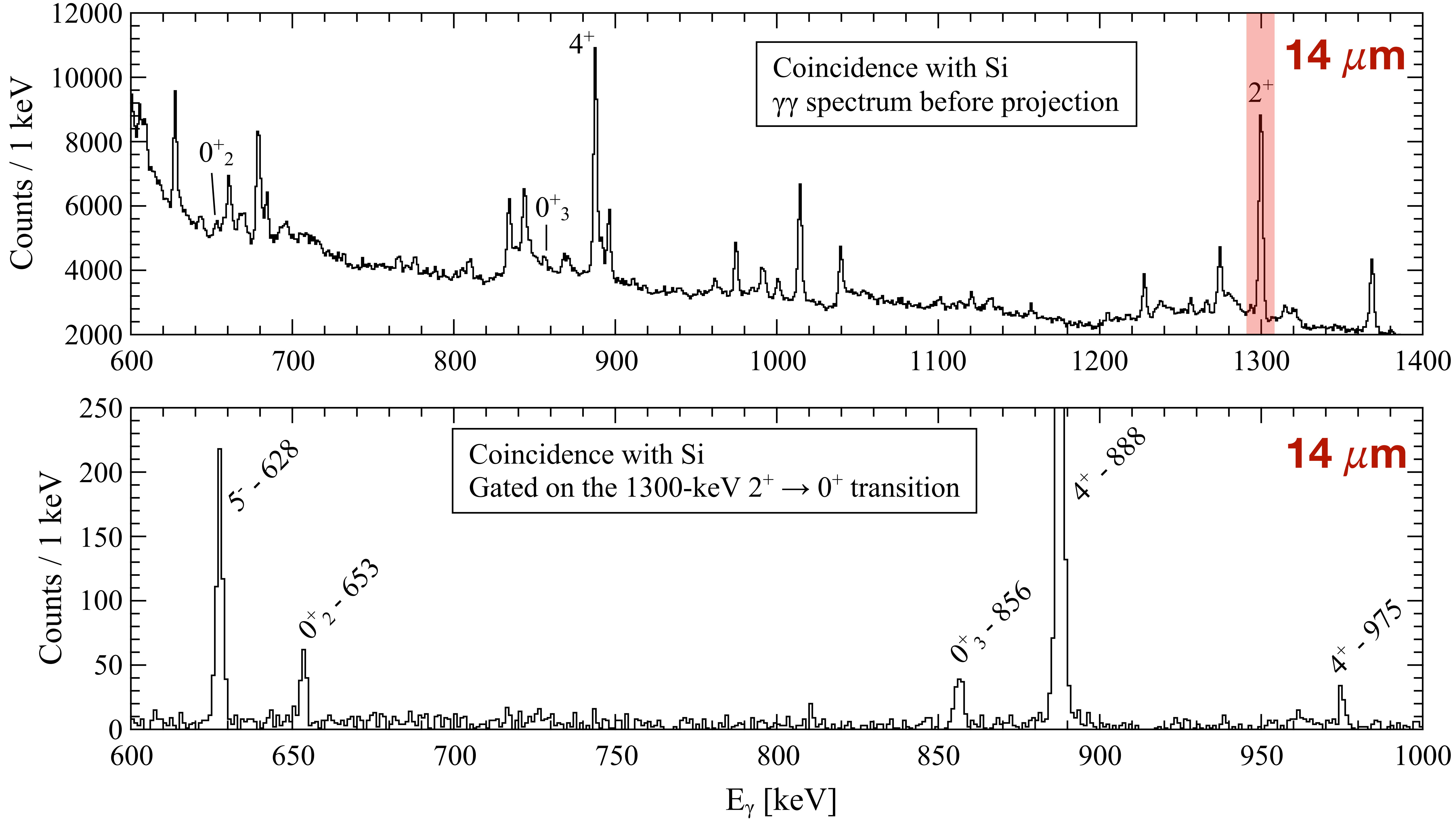


	Counts	Intensity
0^+_2	953	100%
0^+_3	705	74%
0^+_4	190	20%

In the $0^+_4 \rightarrow 2^+_1$ transition, we observe 20% of the counts respect to the $0^+_2 \rightarrow 2^+_1$

No lineshape of 0^+ transitions observed with thick target!

^{114}Sn - $\gamma\gamma$ coincidences

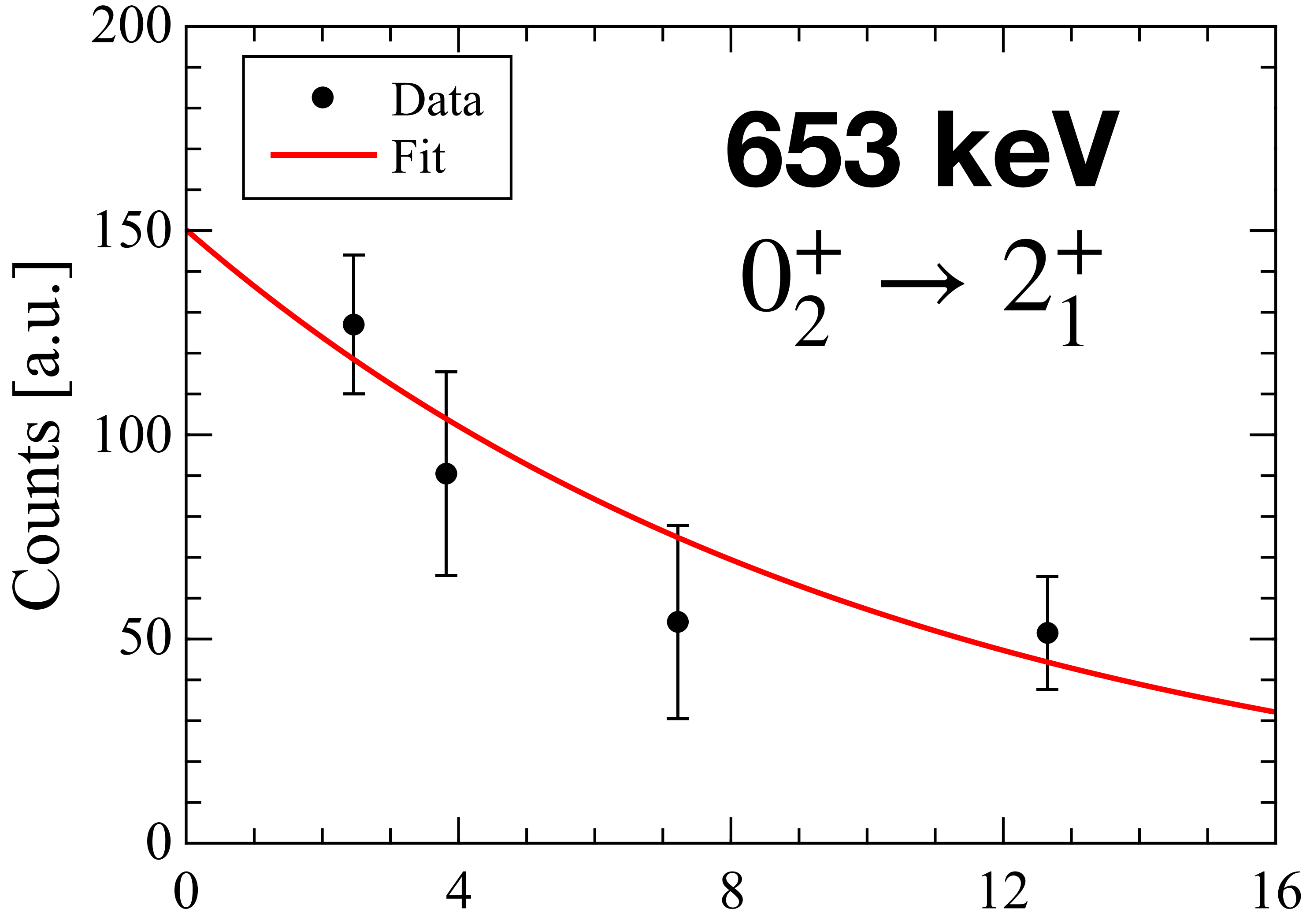


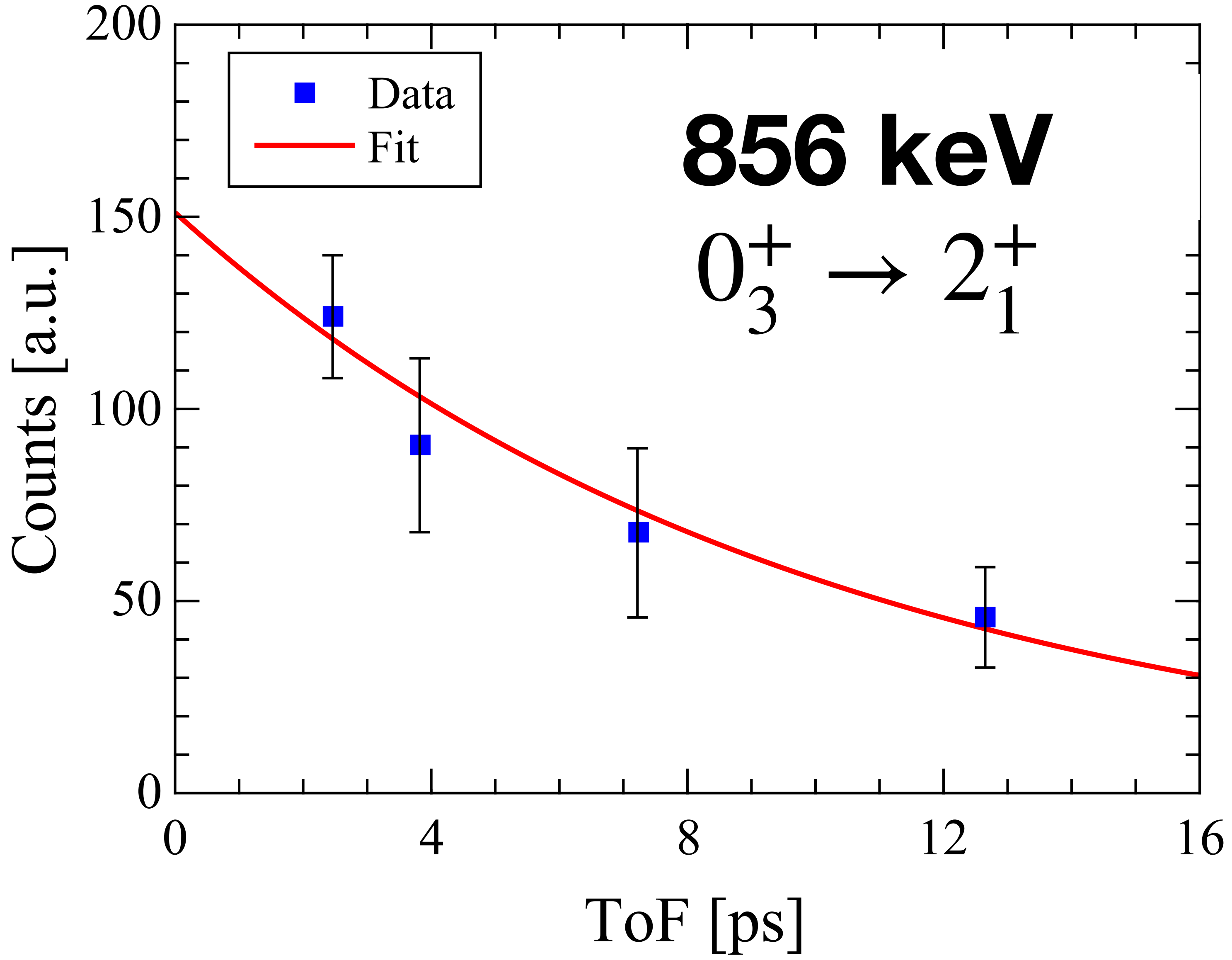
Plunger distances:
14, 22, 42, 74 μm

ToF range: 2 - 15 ps

$\gamma\gamma$ **coincidences** with observation of the **stopped intensities**

^{114}Sn - Lifetimes of 0^+ states





Preliminary results!

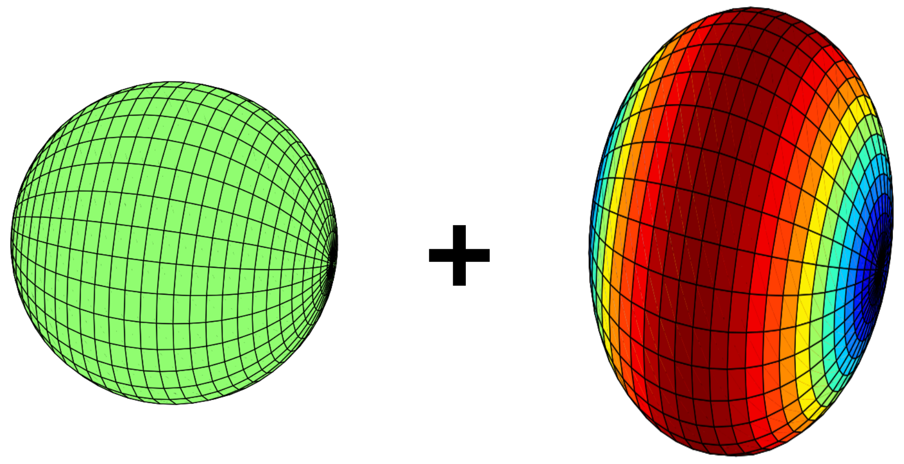
$$T_{1/2} = 7.2 \pm 2.5\ ps$$
$$B(E2) = 20.2 \pm 7.0\ \mathrm{W.u.}$$

Lit: $T_{1/2} = 6.5 \pm 2.3\ ps$

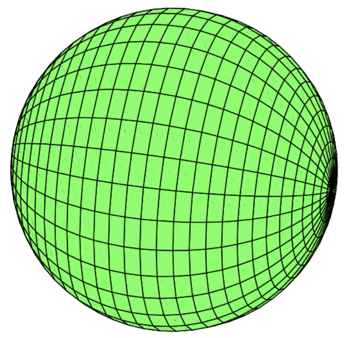
$$T_{1/2} = 6.9 \pm 2.2\ ps$$
$$B(E2) = 5.4 \pm 1.7\ \mathrm{W.u.}$$

Lit: $T_{1/2} > 7.6\ ps$

Possible interpretation



Spherical + Oblate



Spherical

ROSPHERE @ IFIN

^{116,118,120}Sn with different probes

$^{116\text{-}118\text{-}120}$Sn @ IFIN

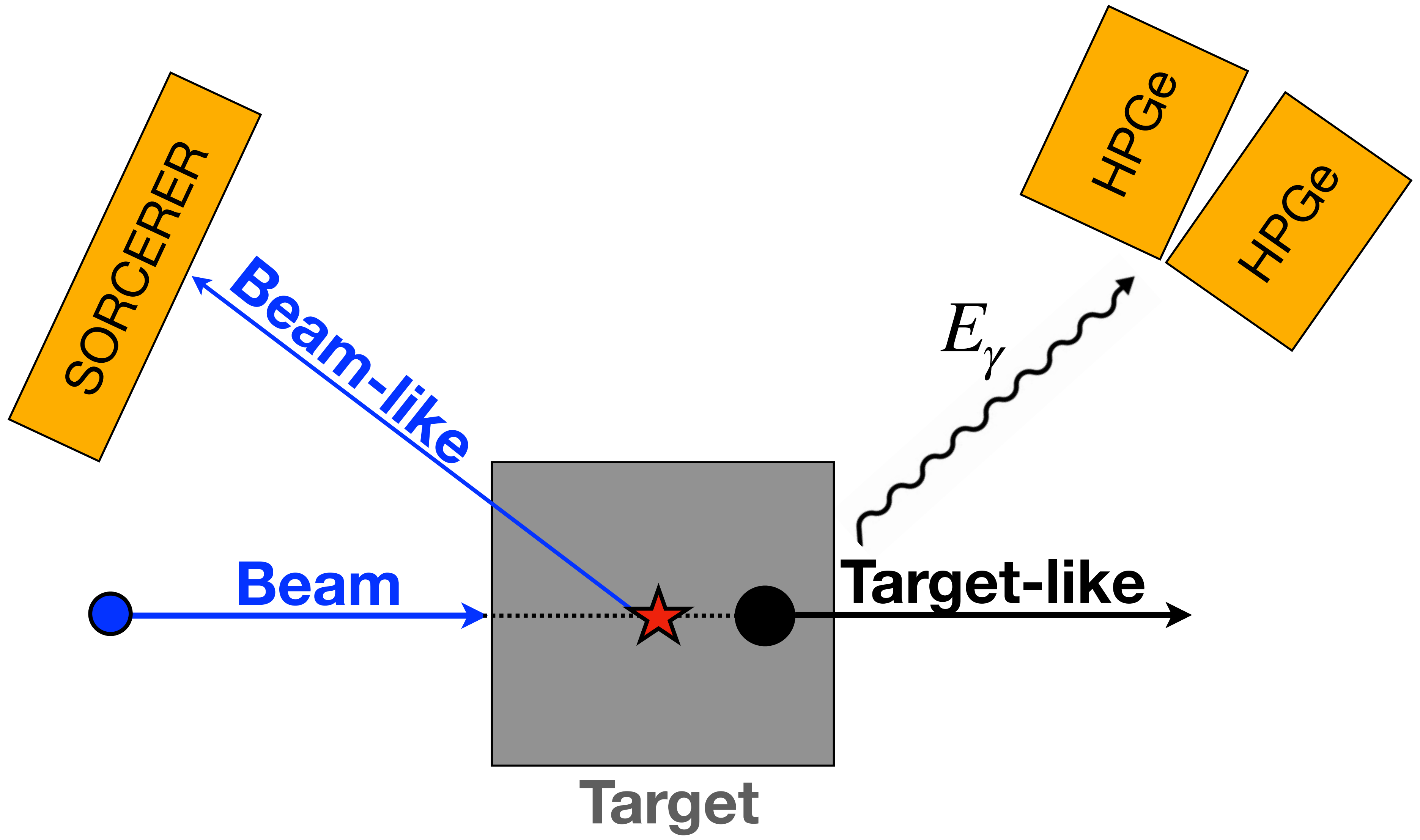
Experiment in Fall 2023

^{13}C+^{117}Sn @ 43 MeV
^{13}C+^{119}Sn @ 43 MeV
^{16}O+^{116}Cd @ 56 MeV

1n, 2p, 1α transfer reactions

^{116}Sn $\Longrightarrow$ +1n
^{118}Sn $\Longrightarrow$ +1n, -1n, -2p
^{120}Sn $\Longrightarrow$ -1n, -1α

D. Bucurescu et al., NIM A 837 (2016) 1–10
T. Beck, C. Costache, R. Lică et al., NIM A 951 (2020) 163090



ROSPHERE

- 18 HPGe + BGO
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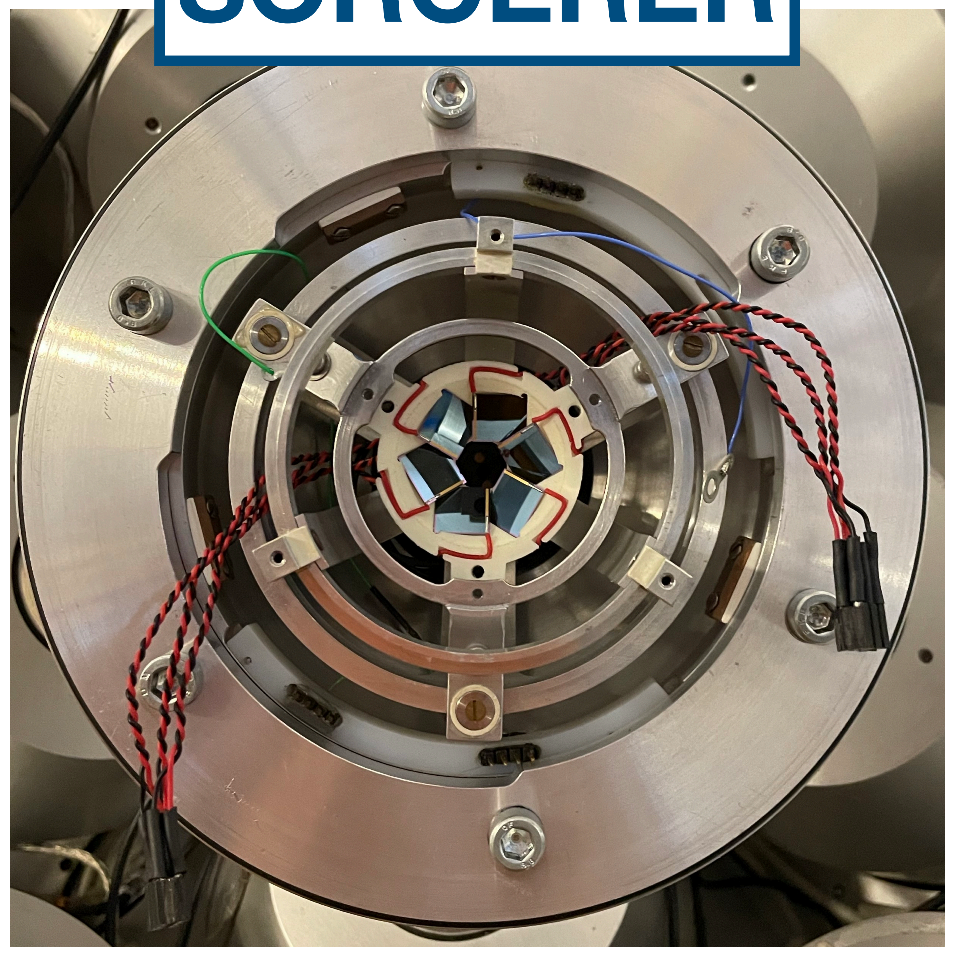
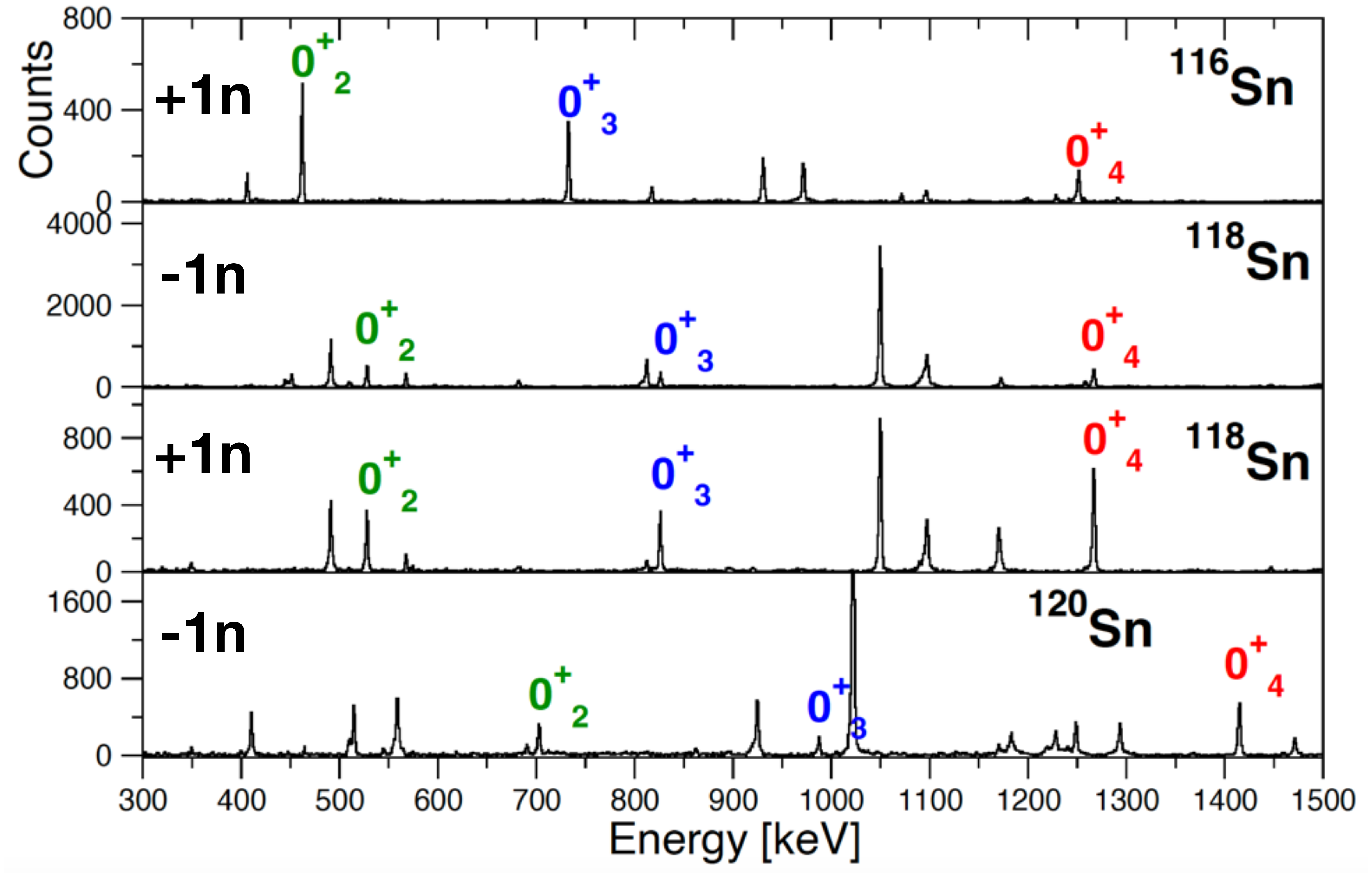
SORCERER



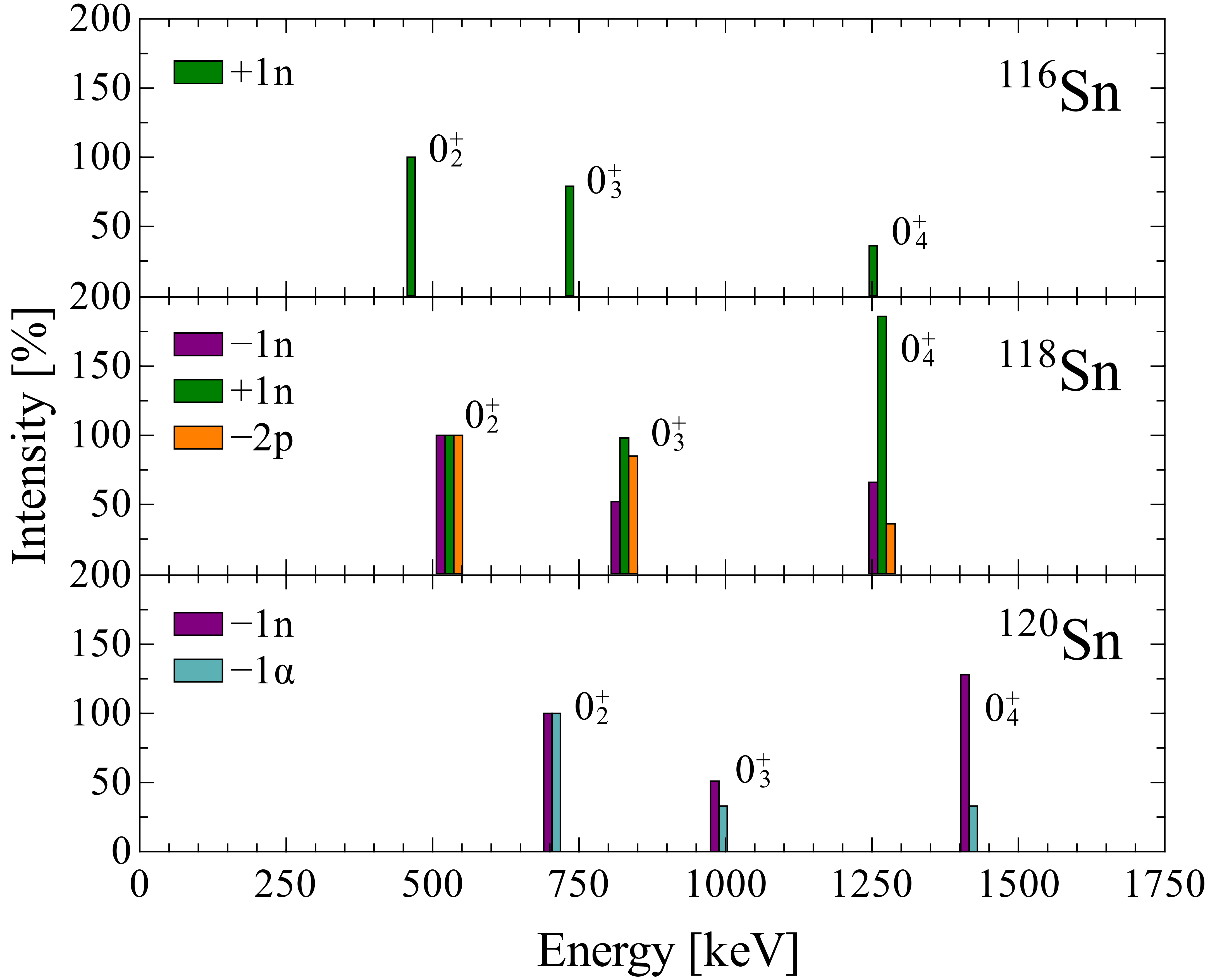
- 6 Si solar cells

$^{116-118-120}$Sn: Spectroscopy and DSAM

$\gamma\gamma$ projections, gated on the $2_1^+ \rightarrow 0_1^+$ transition for the ± 1n reactions



Relative intensities of $0^+ \rightarrow 2_1^+$ transitions



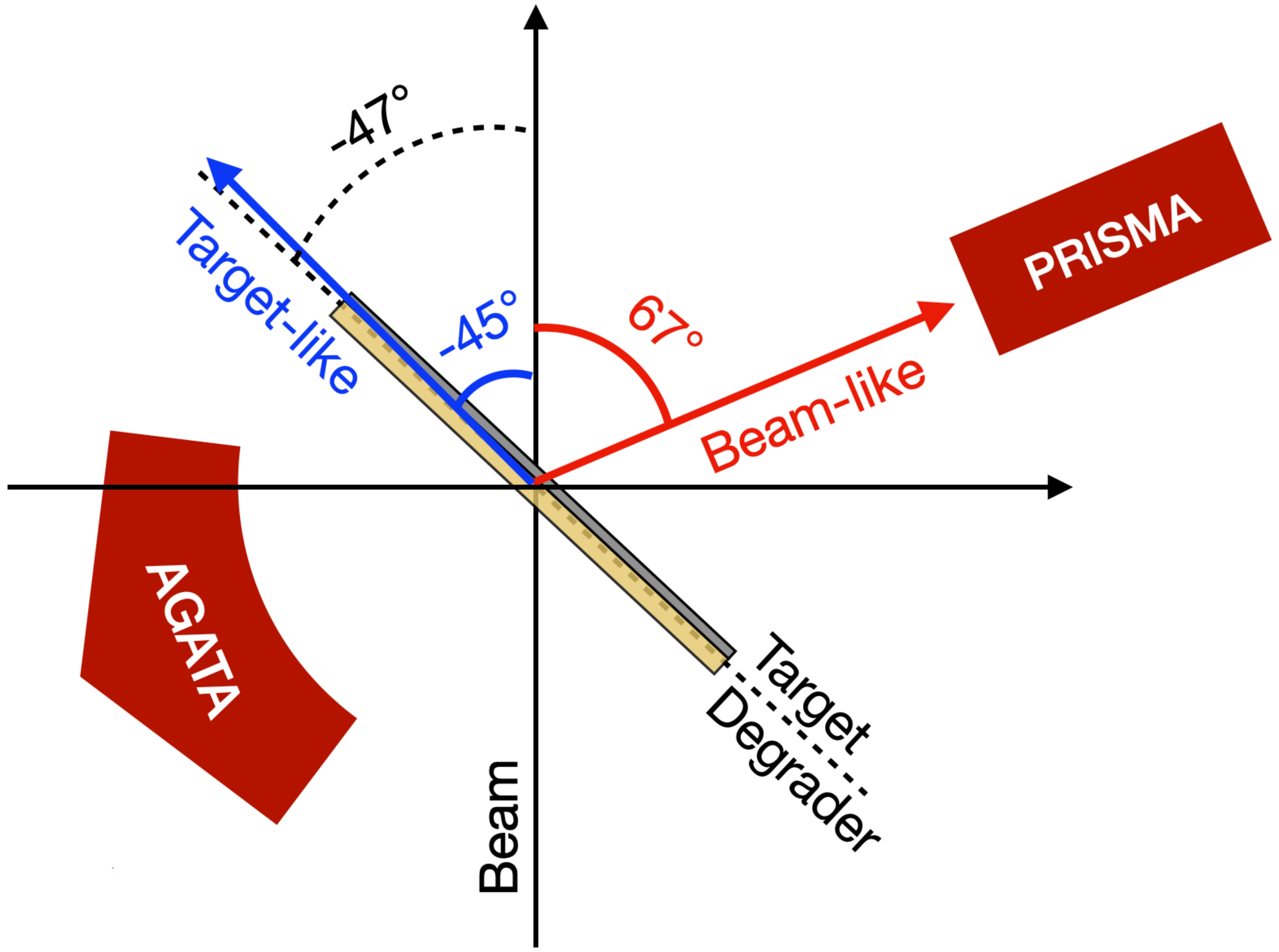
AGATA-PRISMA @ LNL

$^{110-114}$Sn - multi-nucleon transfer

Spectroscopy with PRISMA

$^{32}S + ^{110}Cd$ @ 164 MeV
Multi-nucleon transfer reaction

Effective thick target - DSAM



Master Thesis of **Paolo Pellegrini**

UNIVERSITÀ DEGLI STUDI DI MILANO
FACOLTÀ DI SCIENZE E TECNOLOGIE

Laurea in Fisica

Study of the coexistence of nuclear shapes in the isotopes of Sn and Cd of mass A~110 with the AGATA-PRISMA apparatus

Relatrice:
Prof.ssa Silvia Leoni

Correlatore:
Dott. Simone Bottoni

Candidato:
Paolo Pellegrini

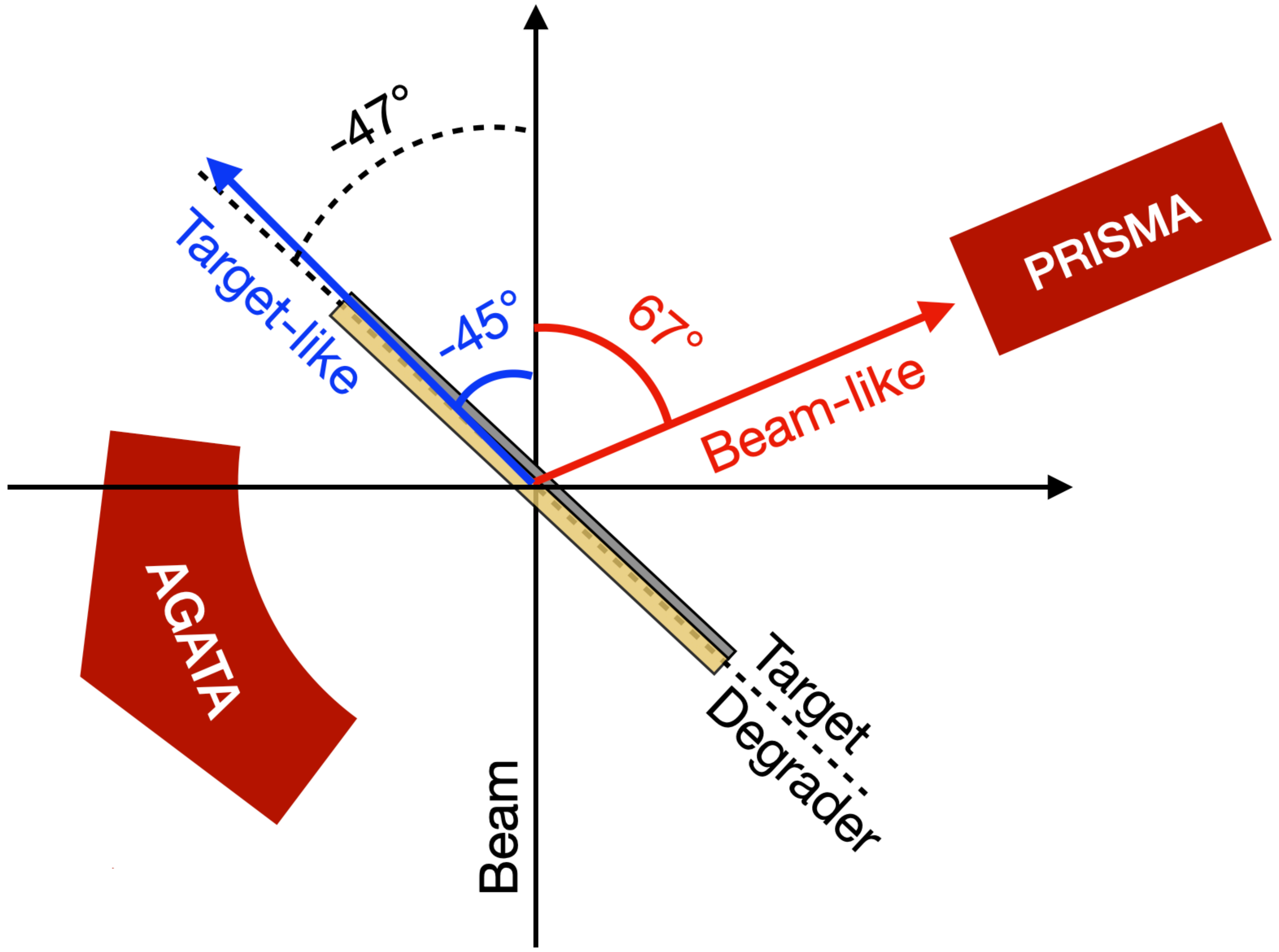
matricola:
465934

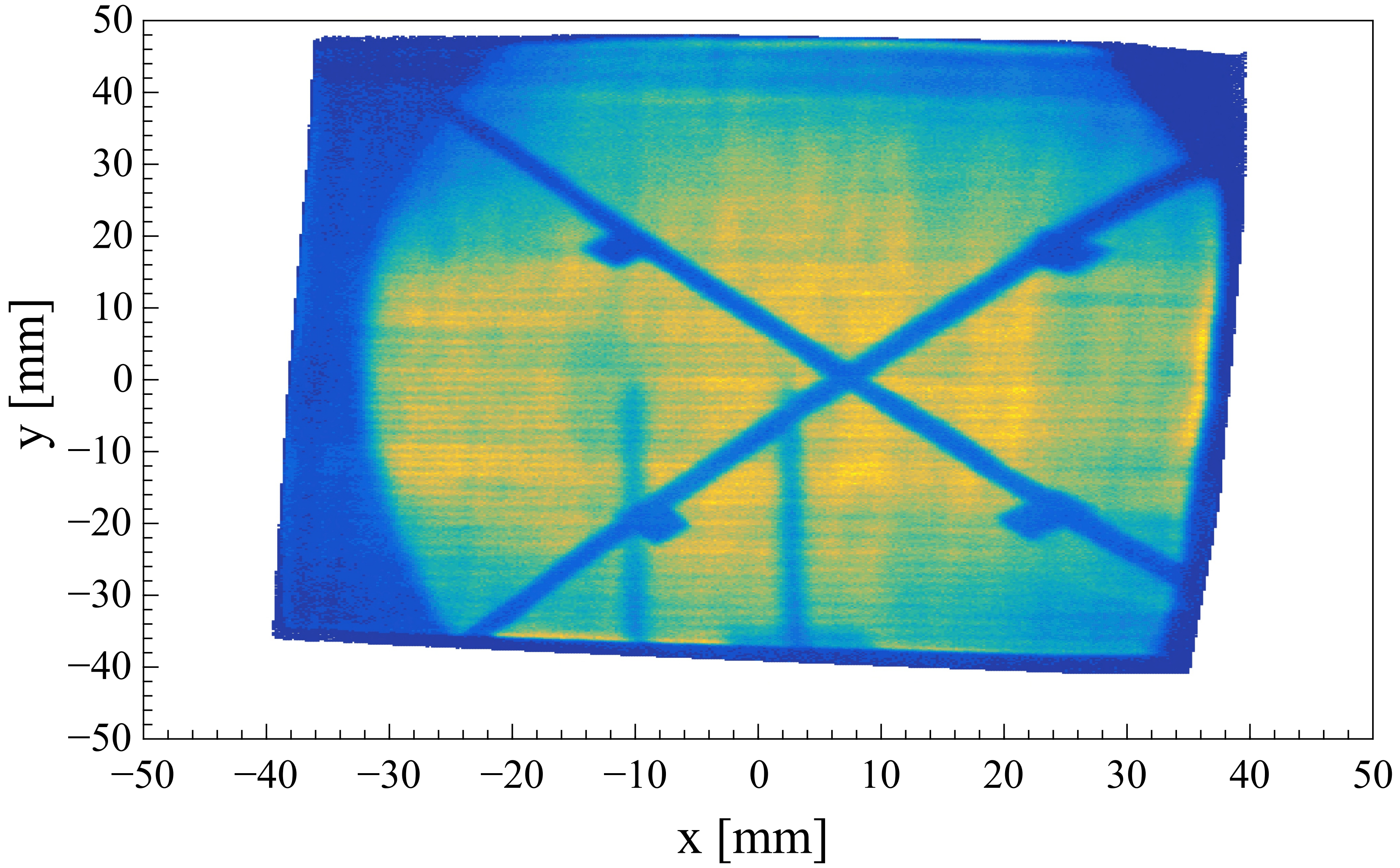
Anno Accademico 2022/2023

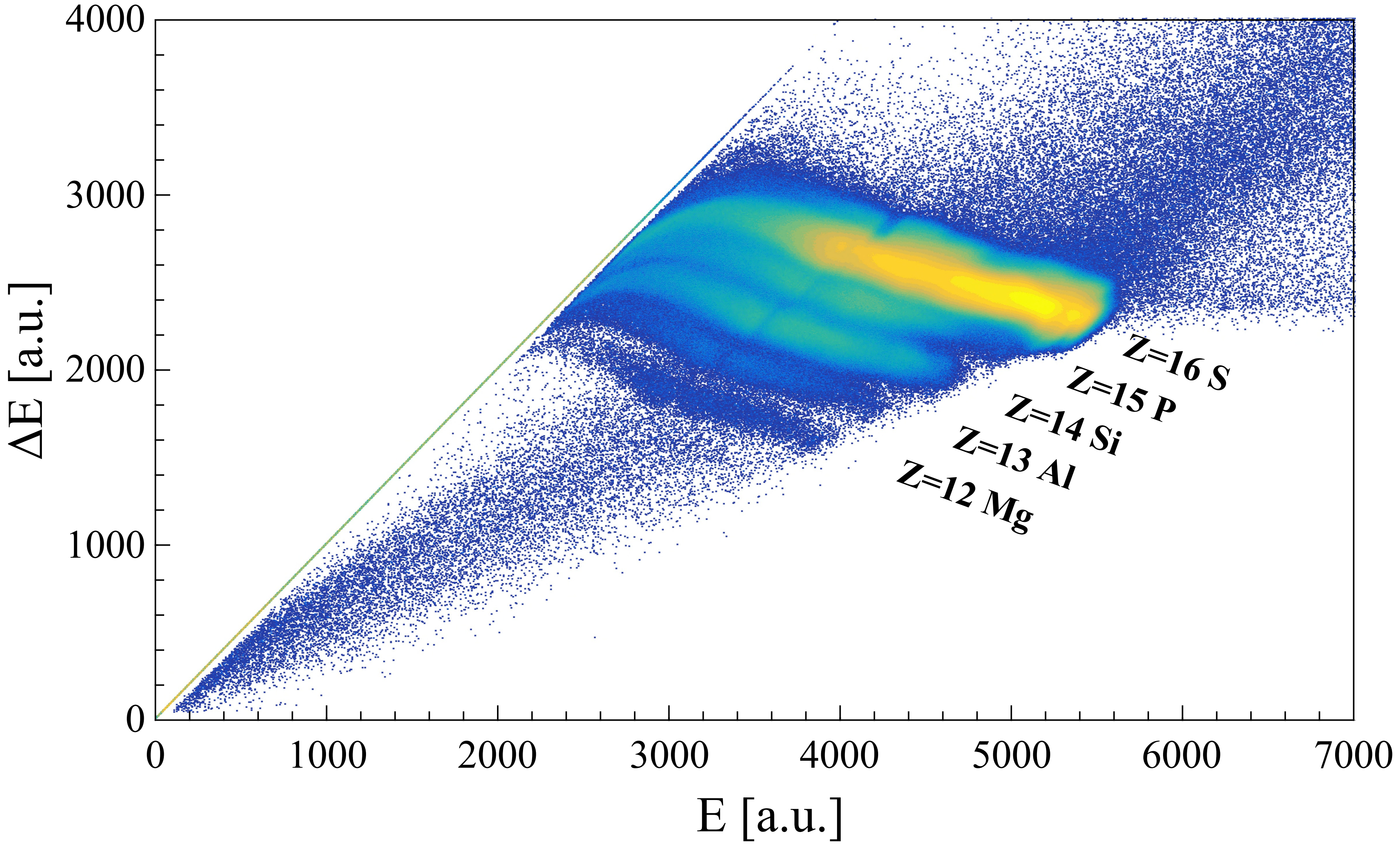
Spectroscopy with PRISMA

$^{32}S + ^{110}Cd$ @ 164 MeV
Multi-nucleon transfer reaction

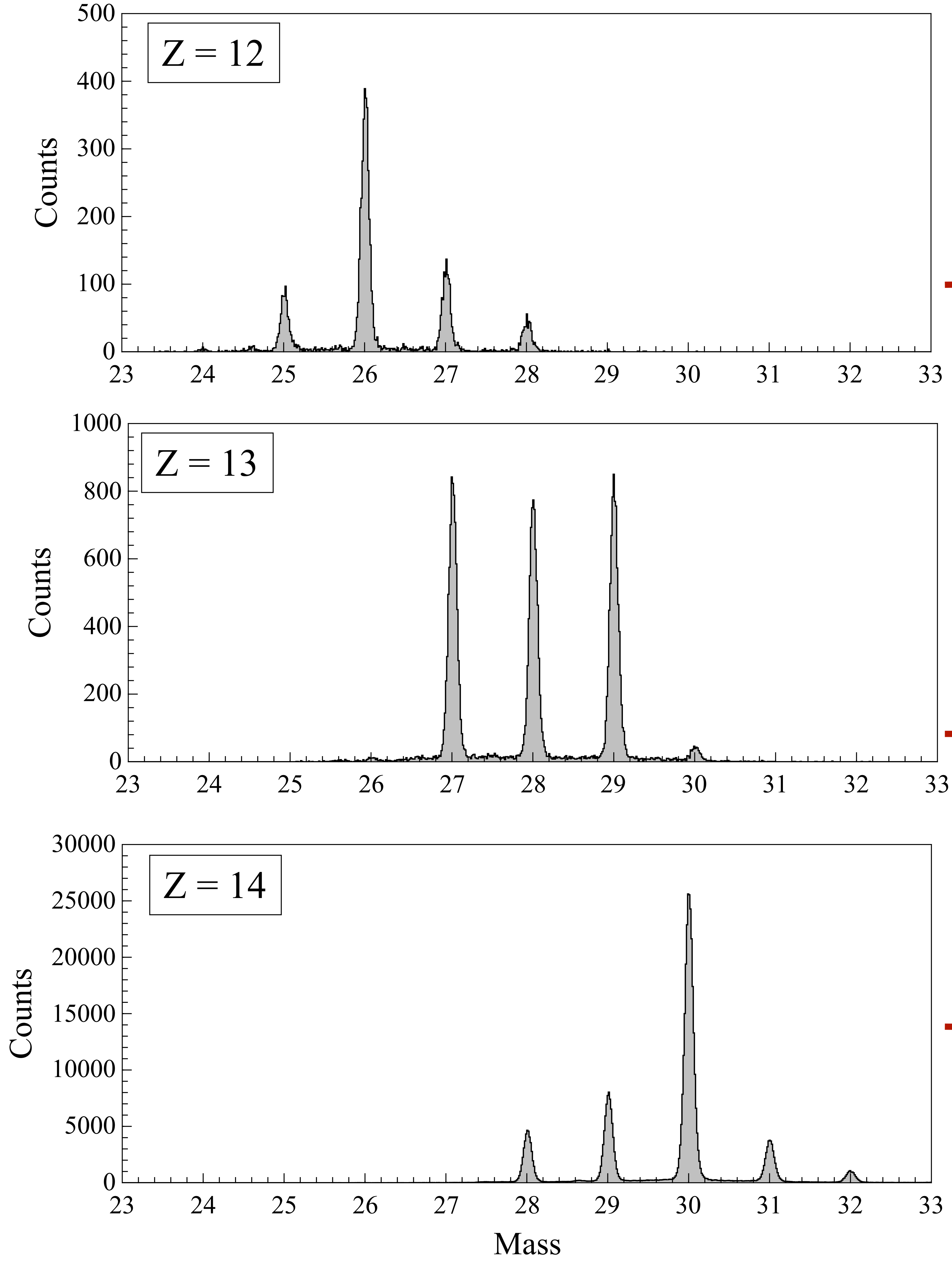
Effective thick target - DSAM







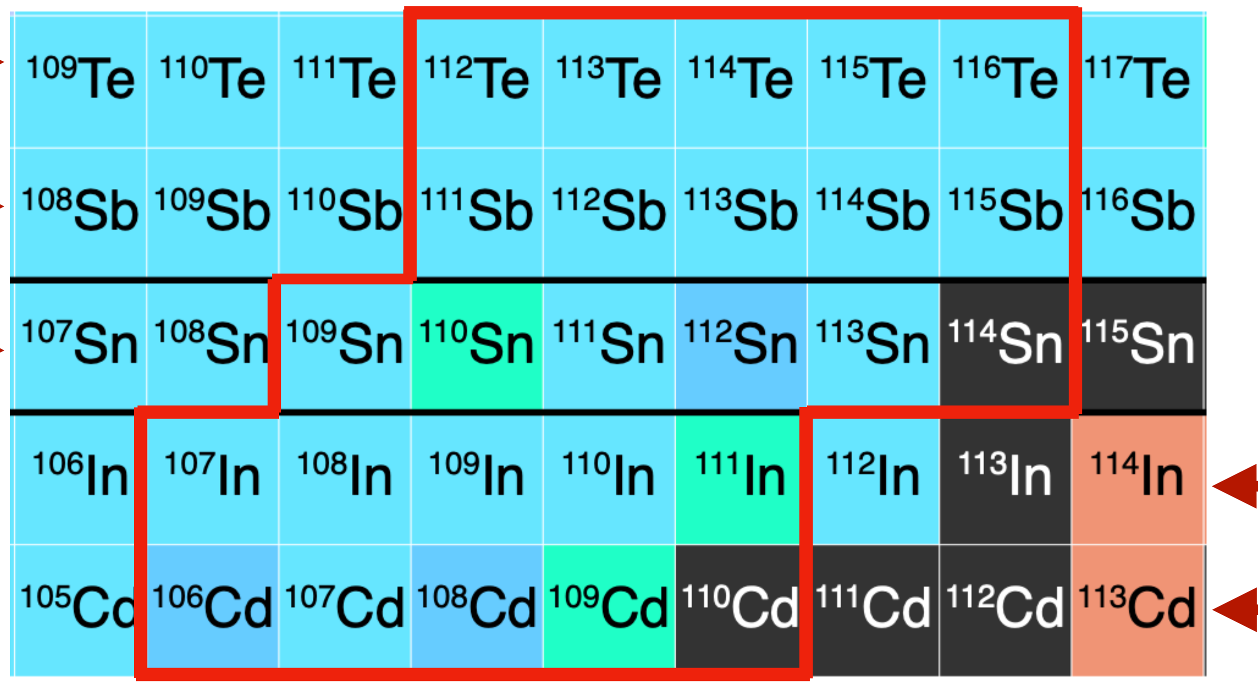
Mass distributions

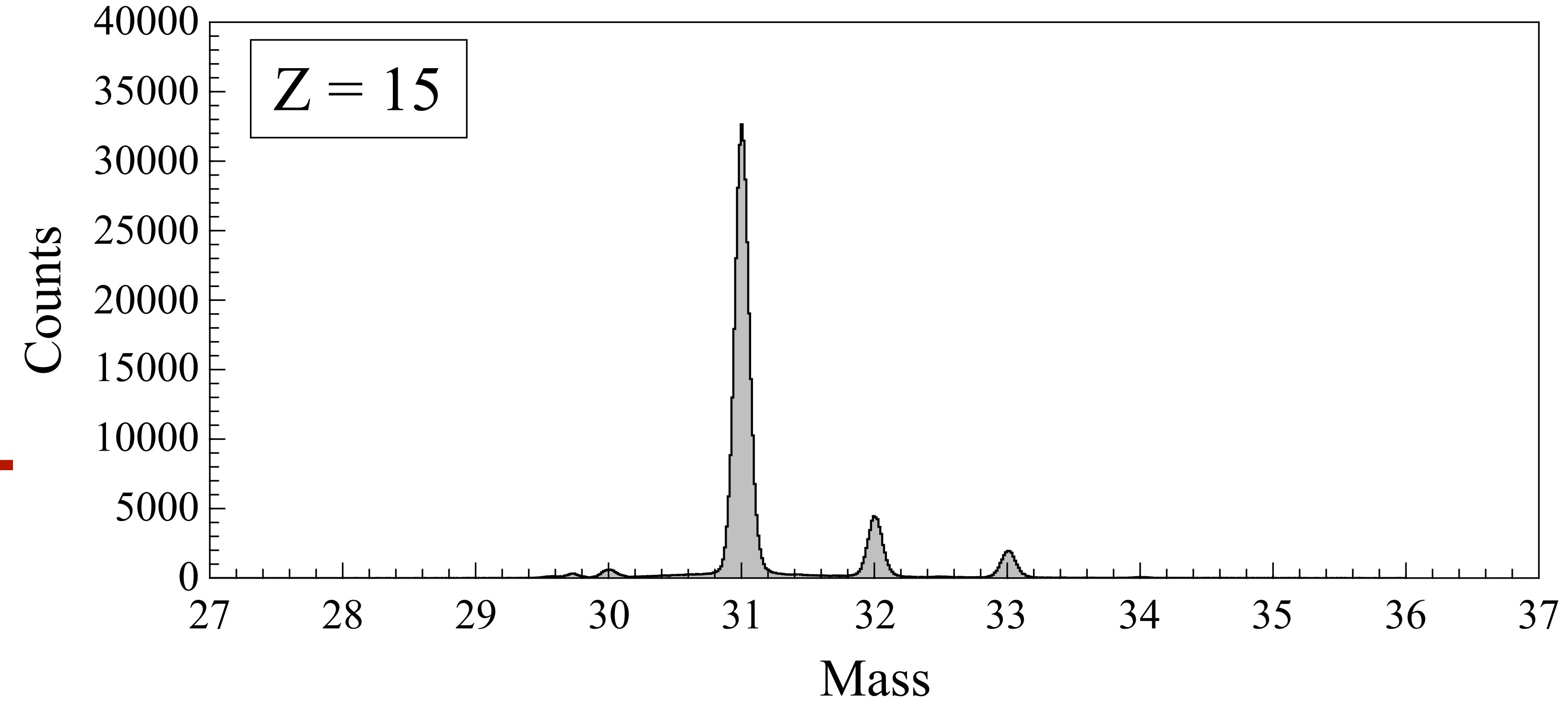


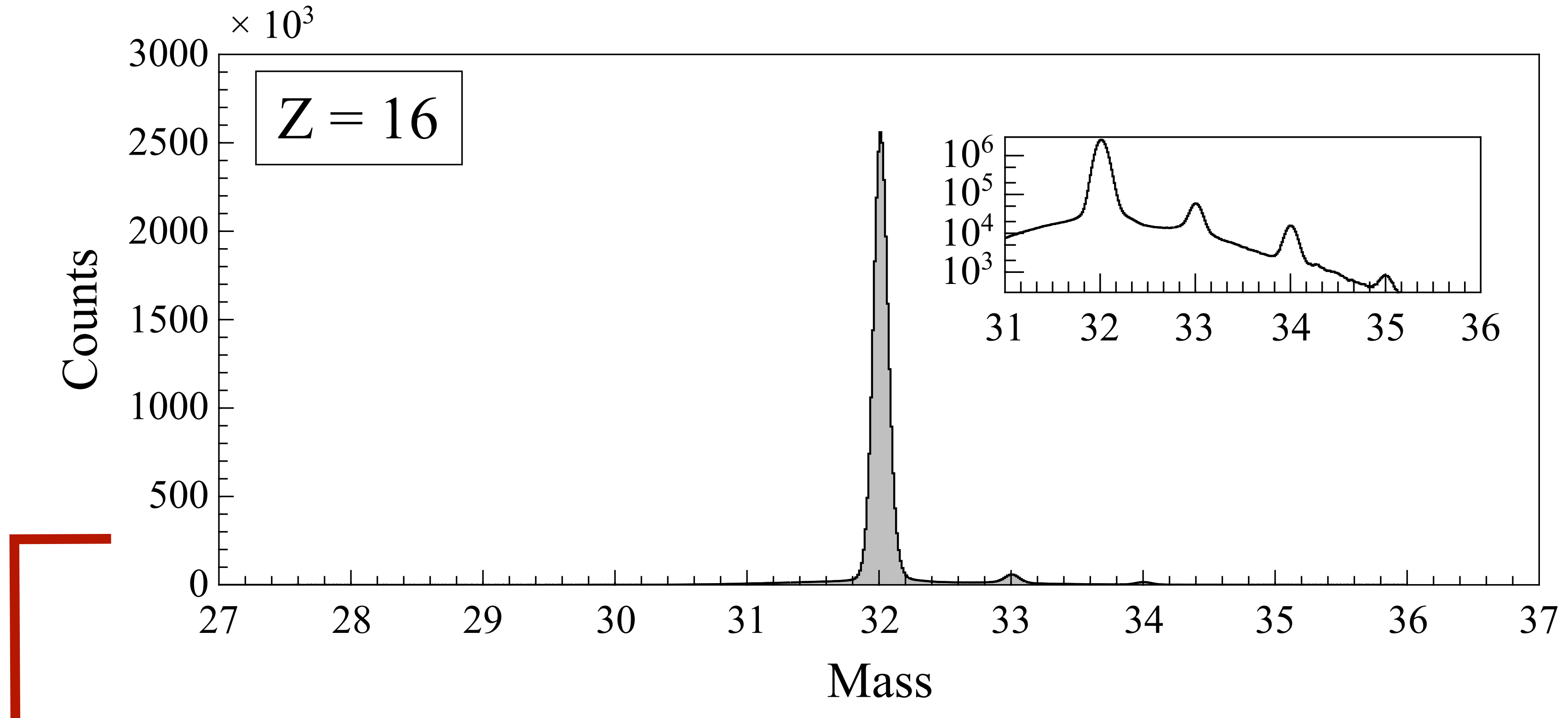
Mass spectra for each Z

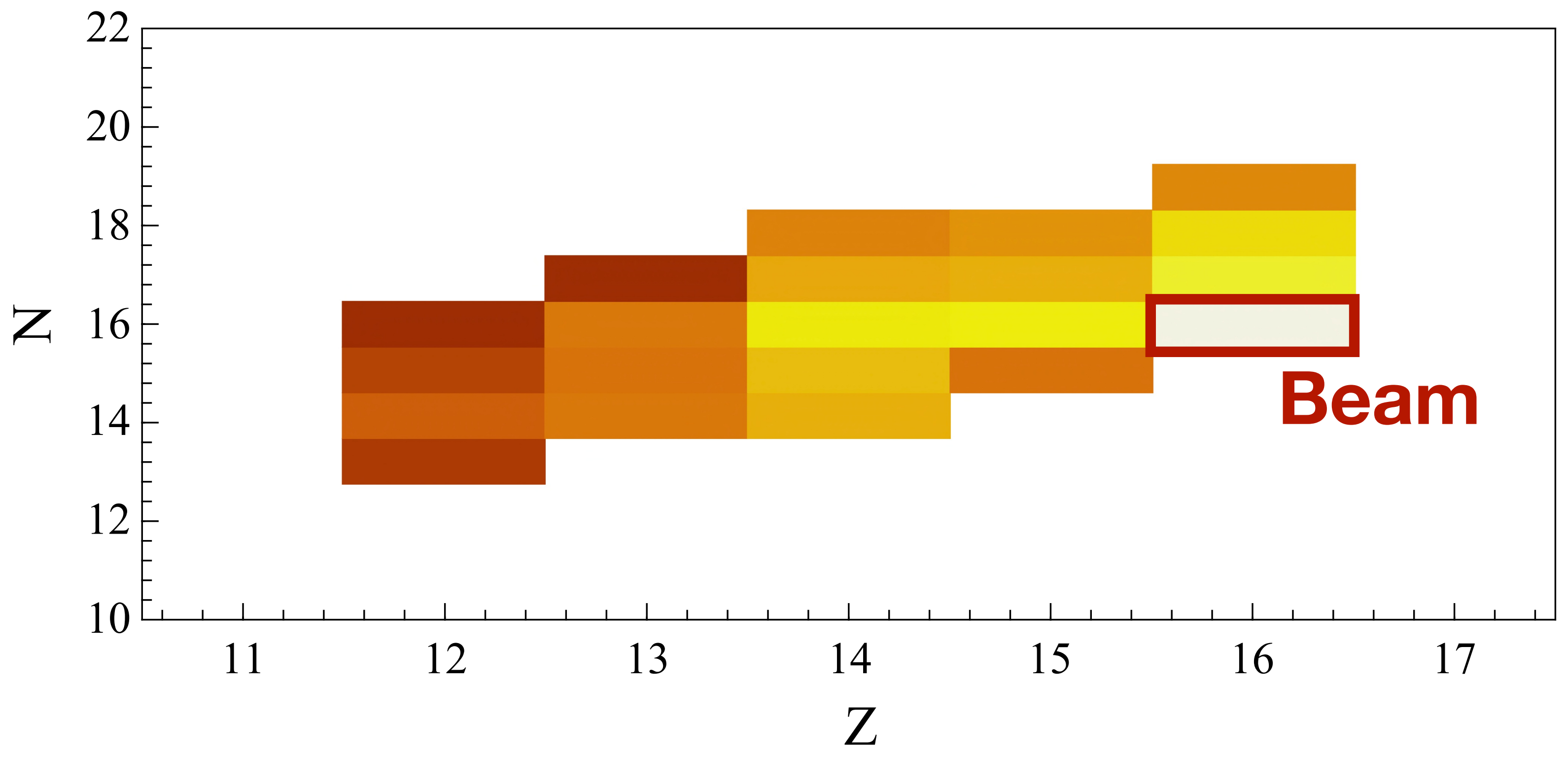
$$\frac{\Delta A}{A} \sim \frac{1}{240}$$

Target-like reaction products





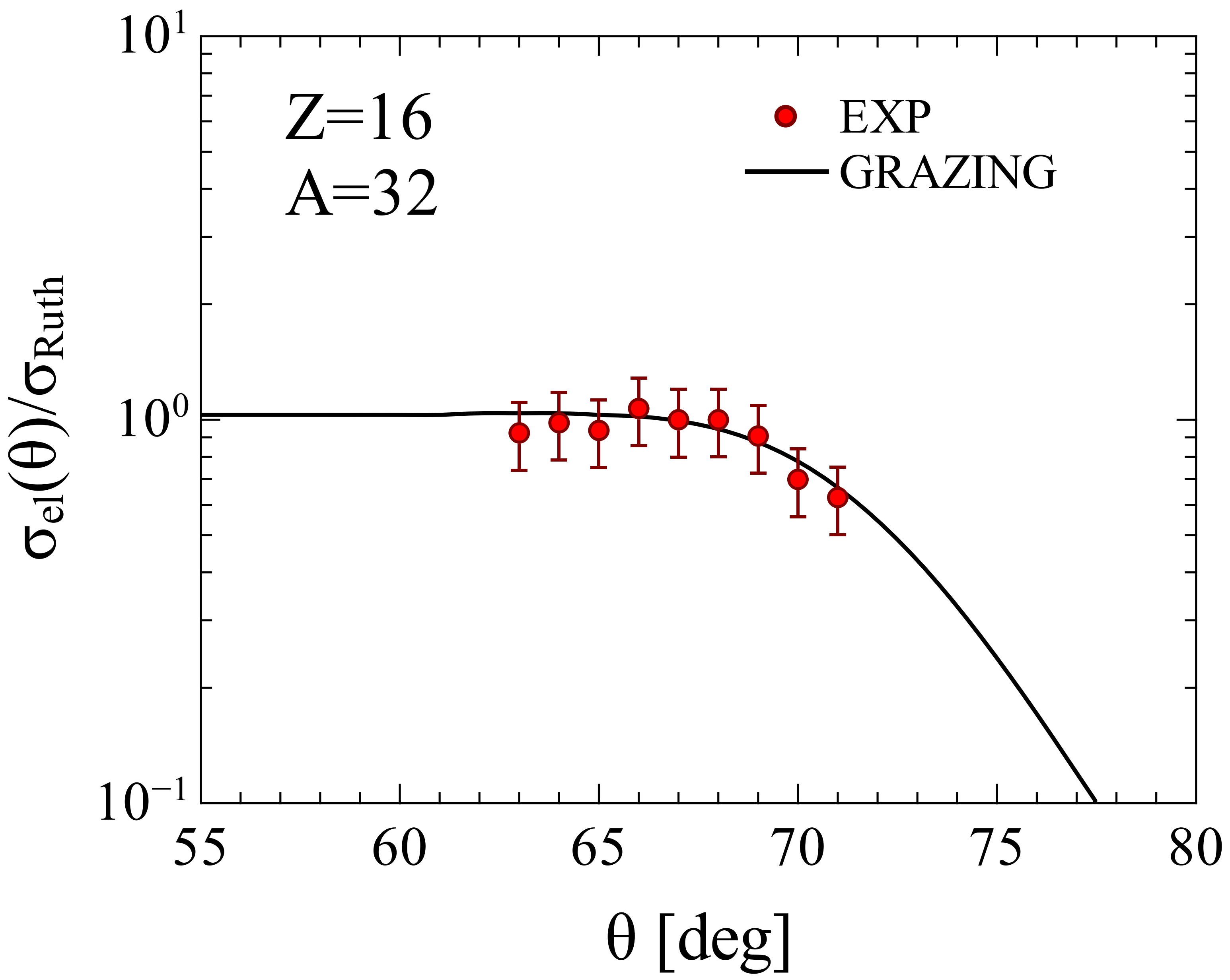


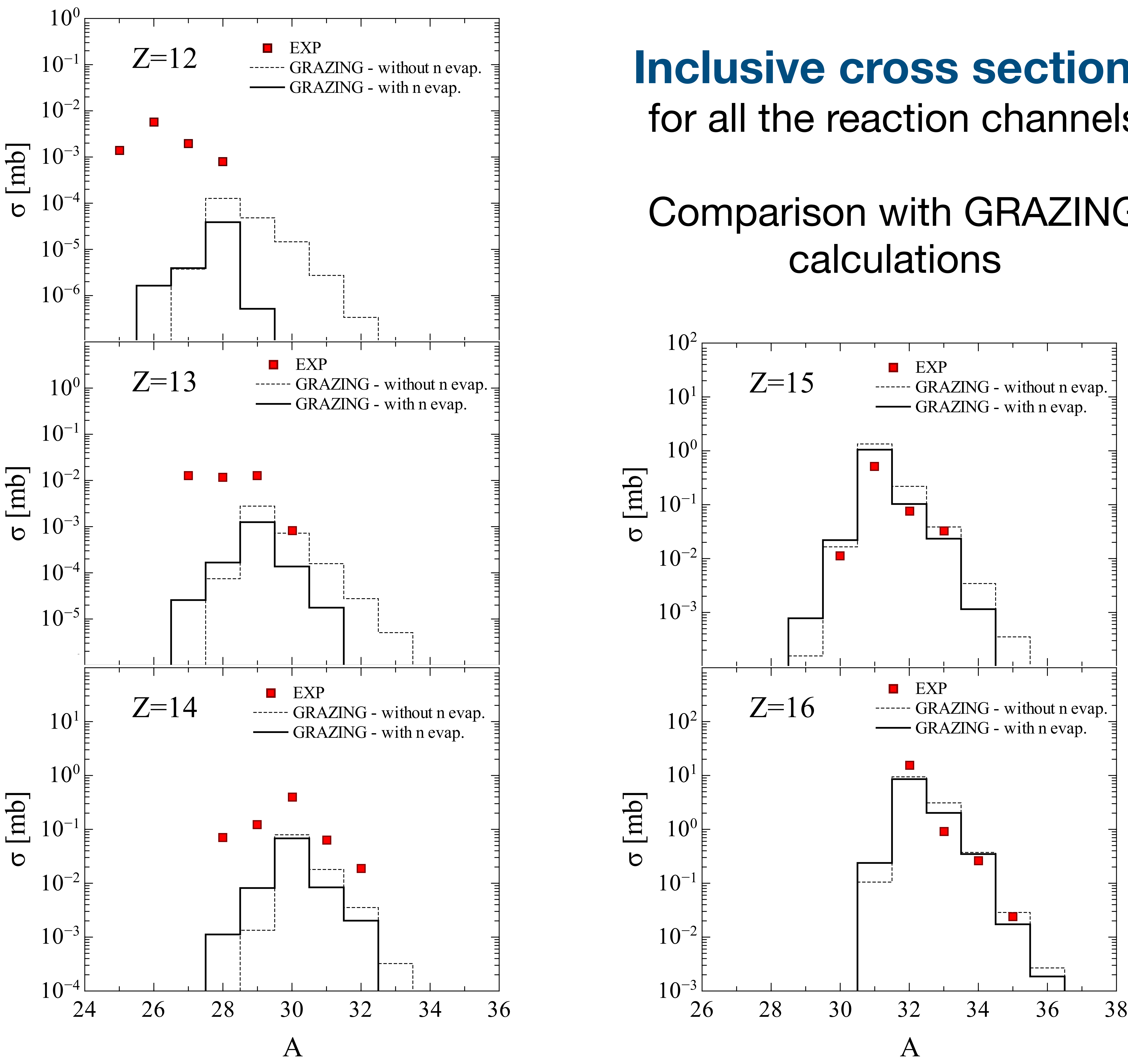


Cross section

Angular distribution
for the quasi-elastic channel

Comparison with GRAZING calculation, normalised on the Rutherford cross section





Inclusive cross sections
for all the reaction channels

Comparison with GRAZING calculations

Summary

- The shape coexistence was investigated in the region of **Sn isotopes around A~110**, by performing multi-nucleon transfer reactions near the Coulomb barrier
- The ongoing analysis will give additional information on the **microscopic structure** of $^{110\text{-}120}$Sn, especially on **reaction mechanism, p/n character of excitations and deformed structures.**

Perspectives

- New lifetime measurements @ IFIN of $^{114\text{-}120}$Sn isotopes scheduled in 2024!
- Final results will be combined and compared with MCSM calculation to pin down the nature of the shape coexistence phenomena in this region

Thank you for your attention!

Collaboration:

G. Corbari[1,2], P. Pellegrini[1], S. Bottoni[1,2], F.C.L. Crespi[1,2], **S. Leoni**[1,2], **N. Mărginean**[4], M. Ciemała[3], **B. Fornal**[3], P. Aguilera[7], M. Balogh[6], J. Benito[7], G. Benzoni[2], M. Boromiza[4], D. Brugnara[6], F. Camera[1,2], S. Carollo[7], G. Ciconali[1,2], N. Cieplicka-Orynczak[3], C. Clisu-Stan[4], G. Colombi[8,1], C. Costache[4], C. Cuciuc[5], A. Ertoprak[6], R. Escudeiro[7], F. Galtarossa[6], D. Filipescu[4], N. Florea[4], I. Gheorge[4], A. Goasduff[6], A. Gottardo[6], A. Ionescu[4], Ł. Iskra[3], S.M. Lenzi[7], R. Lică[4], R. Mărginean[4], M. Matejska-Minda[3], D. Mengoni[7], C. Michelagnoli[8], C. Mihai[4], B. Million[2], D.R. Napoli[6], C. Neacșu[4], A. Negreț[4], C.R. Niță[4], A.Olăcel-Coman[4], T. Otsuka[10], J. Pellumaj[6], R.M. Pèrez-Vidal[6], S. Pigliapoco[7], E. Pilotto[7], M. Polettini[7], F. Recchia[7], K. Rezynkina[7], M. Sedlak[6], M. Sferrazza[9], L. Stan[4], Y. Tsunoda[10], A. Turturică[4], S. Ujeniuc[4], J.J. Valiente-Dobòn[6], O. Wieland[2], I. Zanon[6], L. Zago[7], G. Zhang[7], H. Zhen[7]

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[5] Extreme Light Infrastructure, Nuclear Physics, Măgurele, Romania
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[7] Dipartimento di Fisica and INFN, Sezione di Padova, Padova, Italy
[8] Institut Laue-Langevin, Grenoble, France
[9] Université libre de Bruxelles (ULB), Belgium
[10] University of Tokyo, Tokyo, Japan

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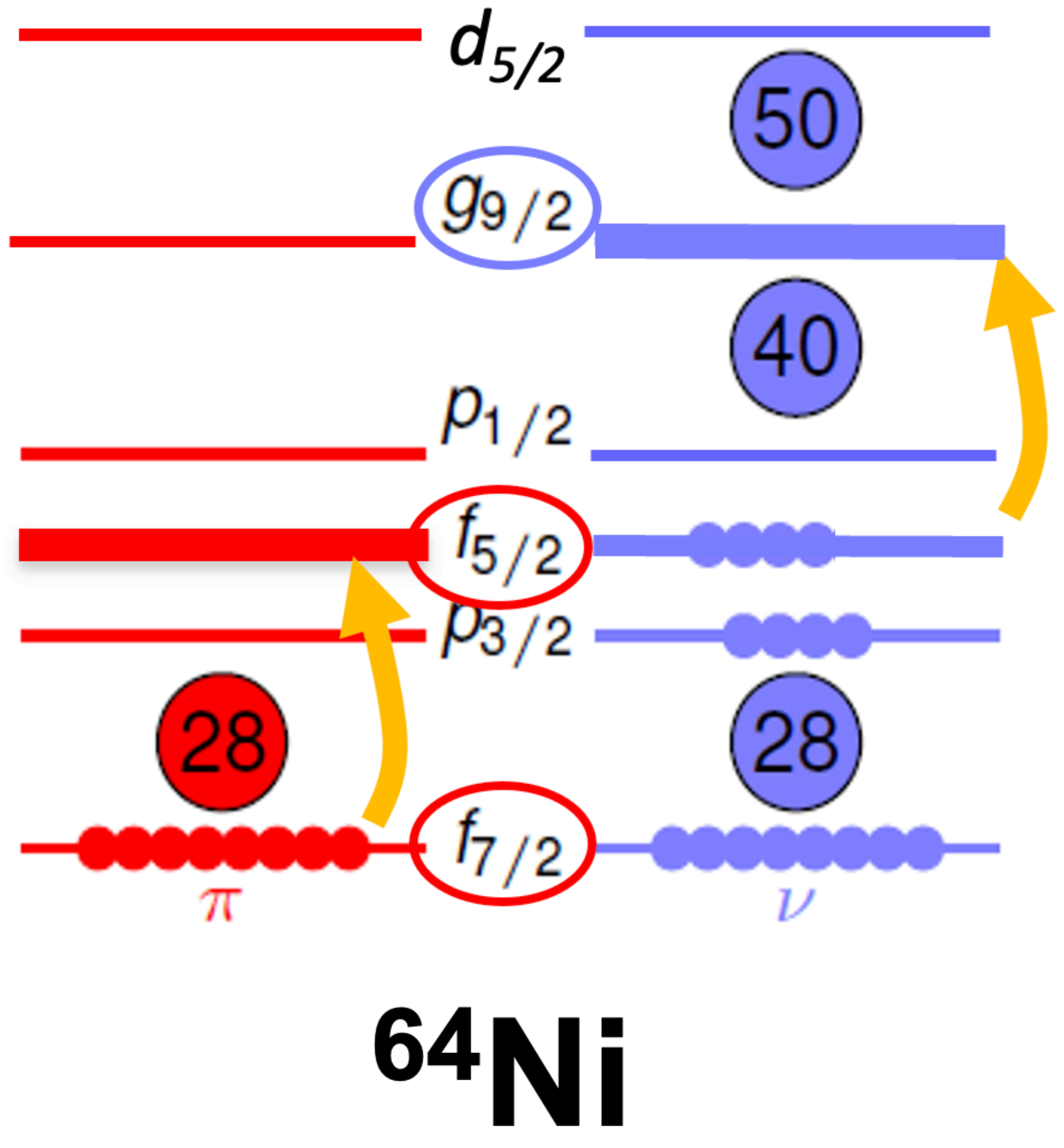
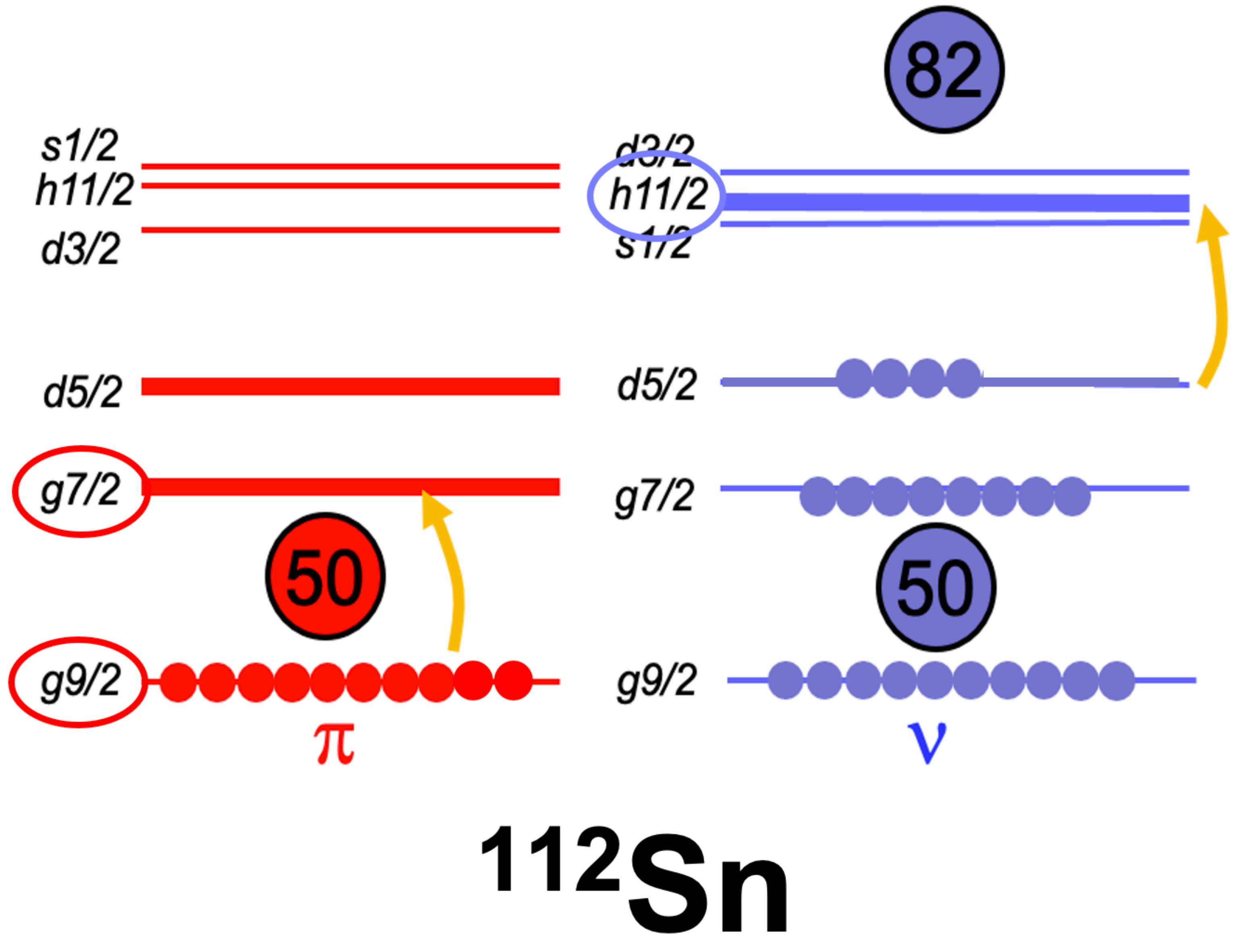
IFIN-HH
eli nuclear physics
東京大学 THE UNIVERSITY OF TOKYO
NEUTRONS FOR SCIENCE
ULB

Backup slides

Backup - Monopole-driven excitations





- Spontaneus symmetry breaking due to p-n interaction
- Driven by the **monopole part of the tensor force**
- Neutron excitation in $g_{9/2}$ induces a **reduction** of the **$f_{5/2}$-$f_{7/2}$ splitting** (Z=28 shell gap)

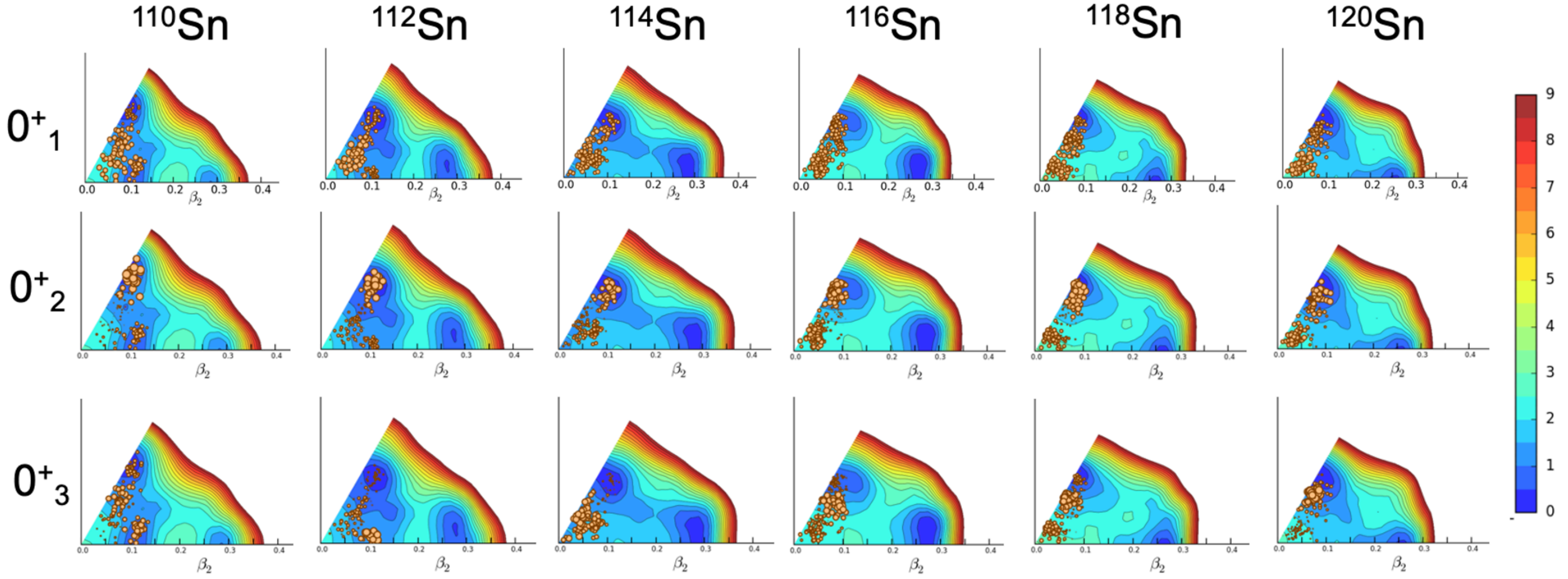
Analogy with $^{112\text{-}114}$Sn isotopes

Neutron excitation in $h_{11/2}$ induces a **reduction** of the **$g_{7/2}$-$g_{9/2}$ splitting** (Z=50 shell gap)

S. Leoni et al., Phys. Rev. Lett. 118, 162502 (2017)

N. Mărginean et al., Phys. Rev. Lett. 125, 102502 (2020)

Backup - MCSM calculations



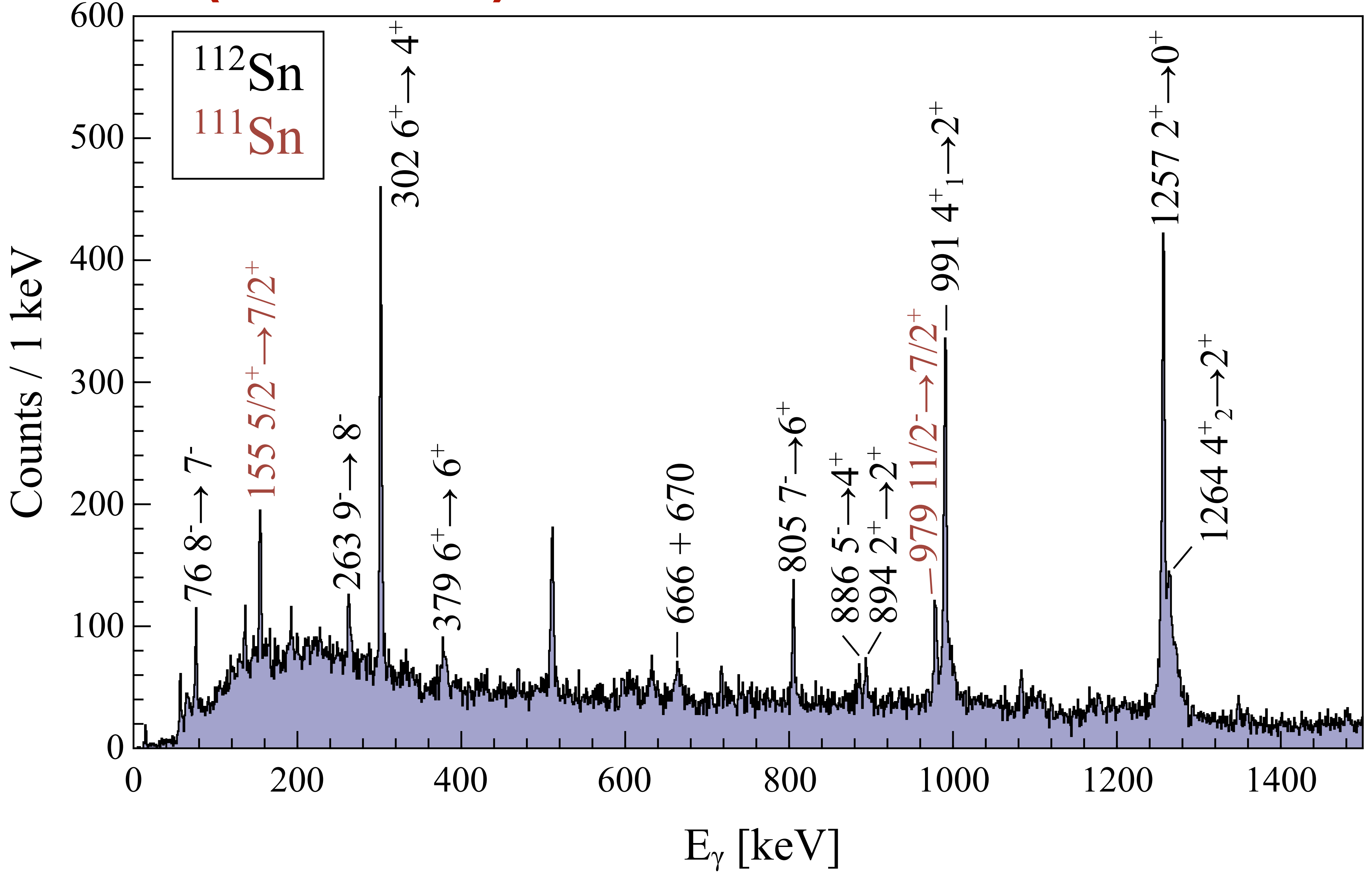
Preliminary calculations!

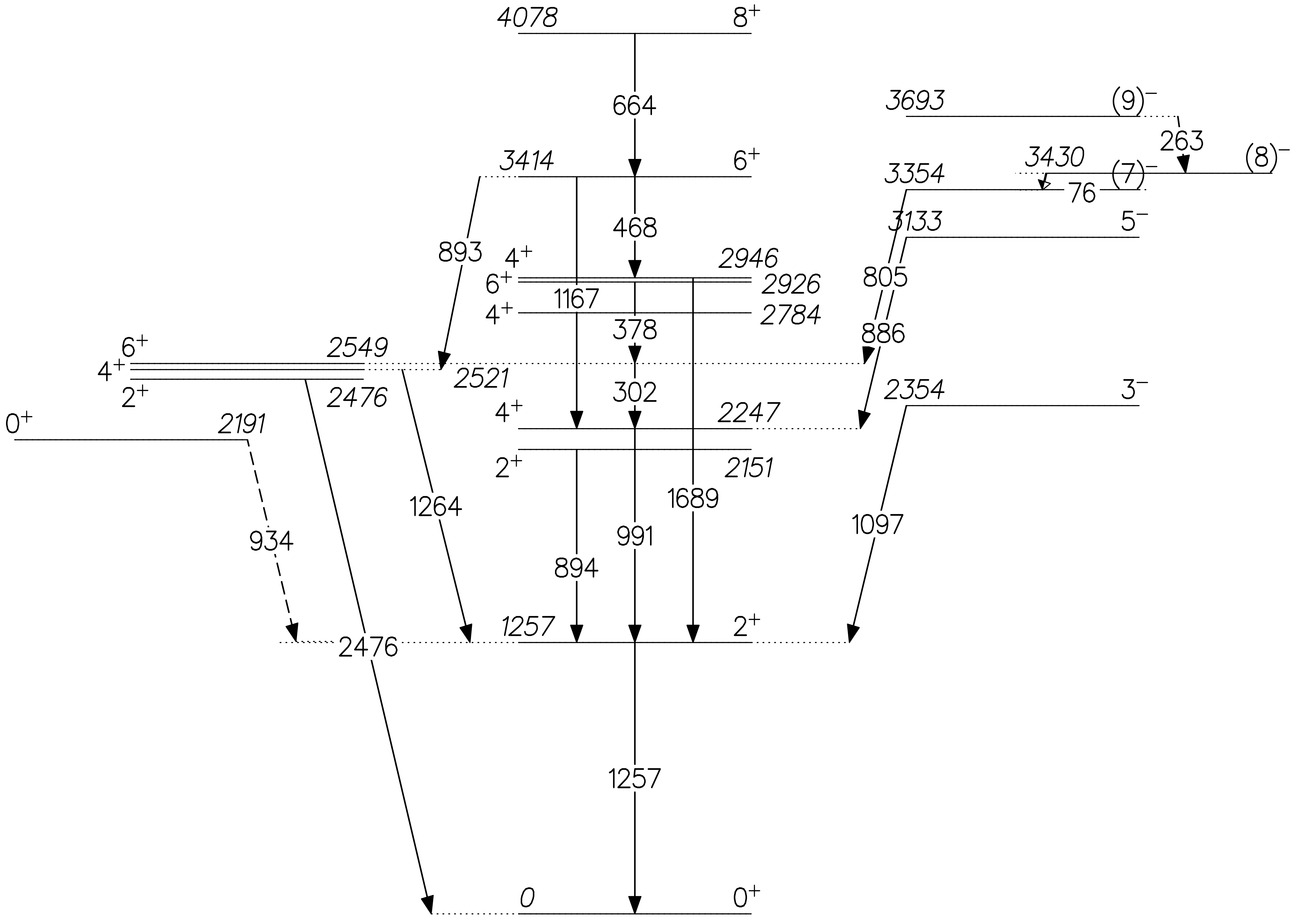
T. Otzuka, Y. Tsunoda, to be published.

T. Togashi et al., Phys. Rev. Lett. 121, 062501 (2018).

Backup - Ion-gated γ spectra

- Study of population of states with MNT
- Observation of low-spin states up to $J_{max} = 9$
- Transitions of states with $T_{1/2} \gtrsim ps$

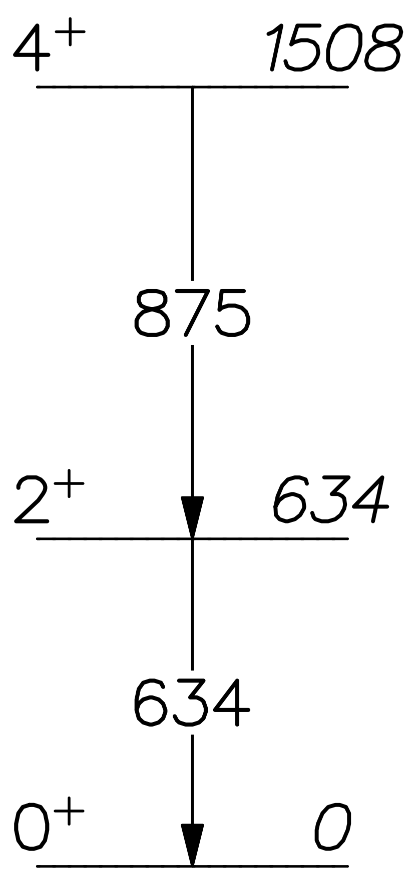




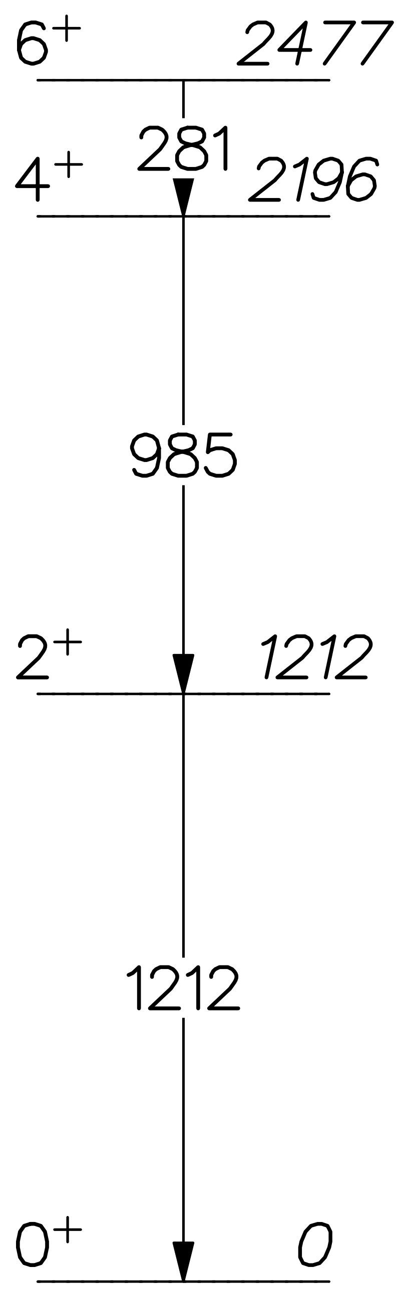
112Sn

Backup

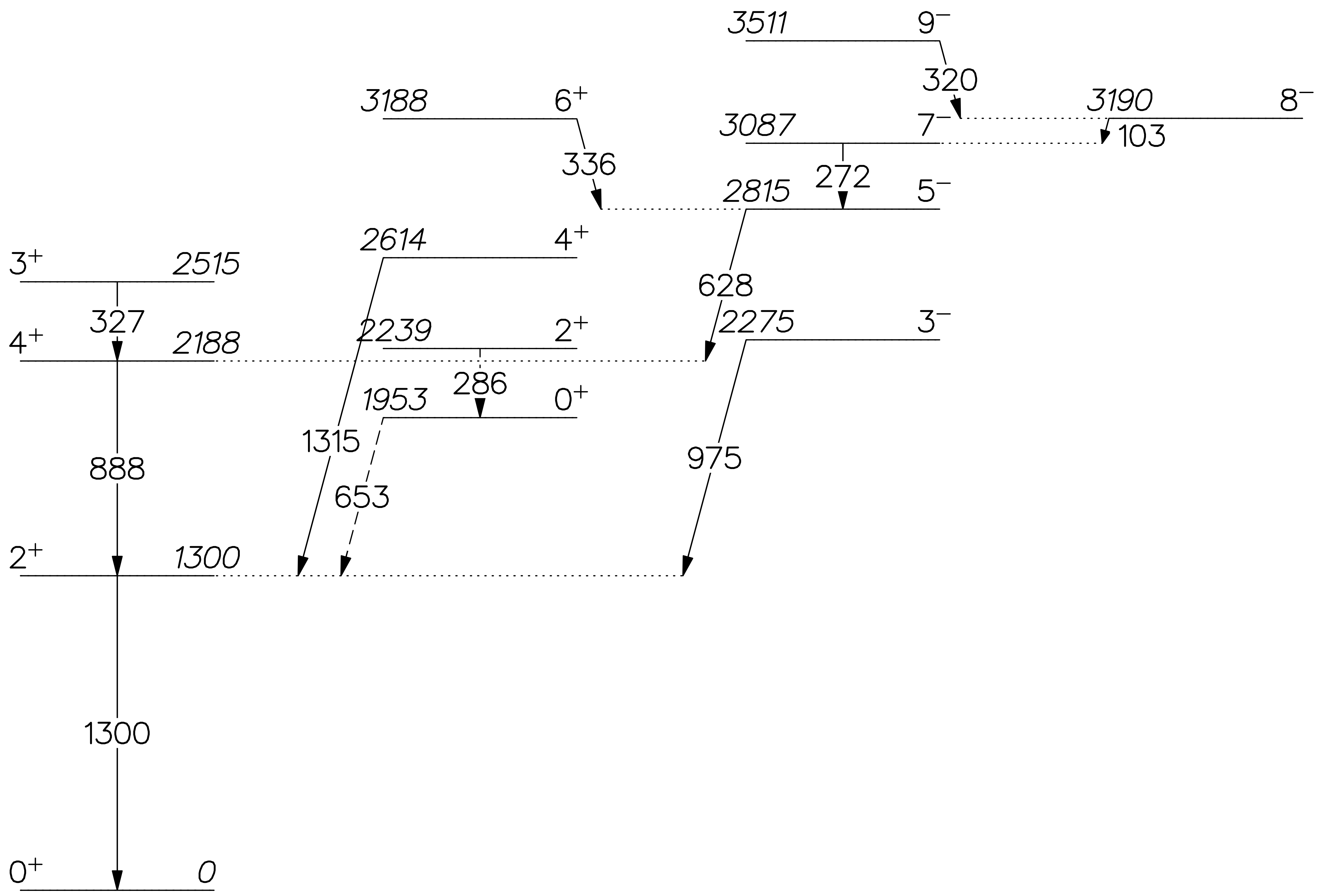
AGATA-PRISMA level schemes



^{108}Cd

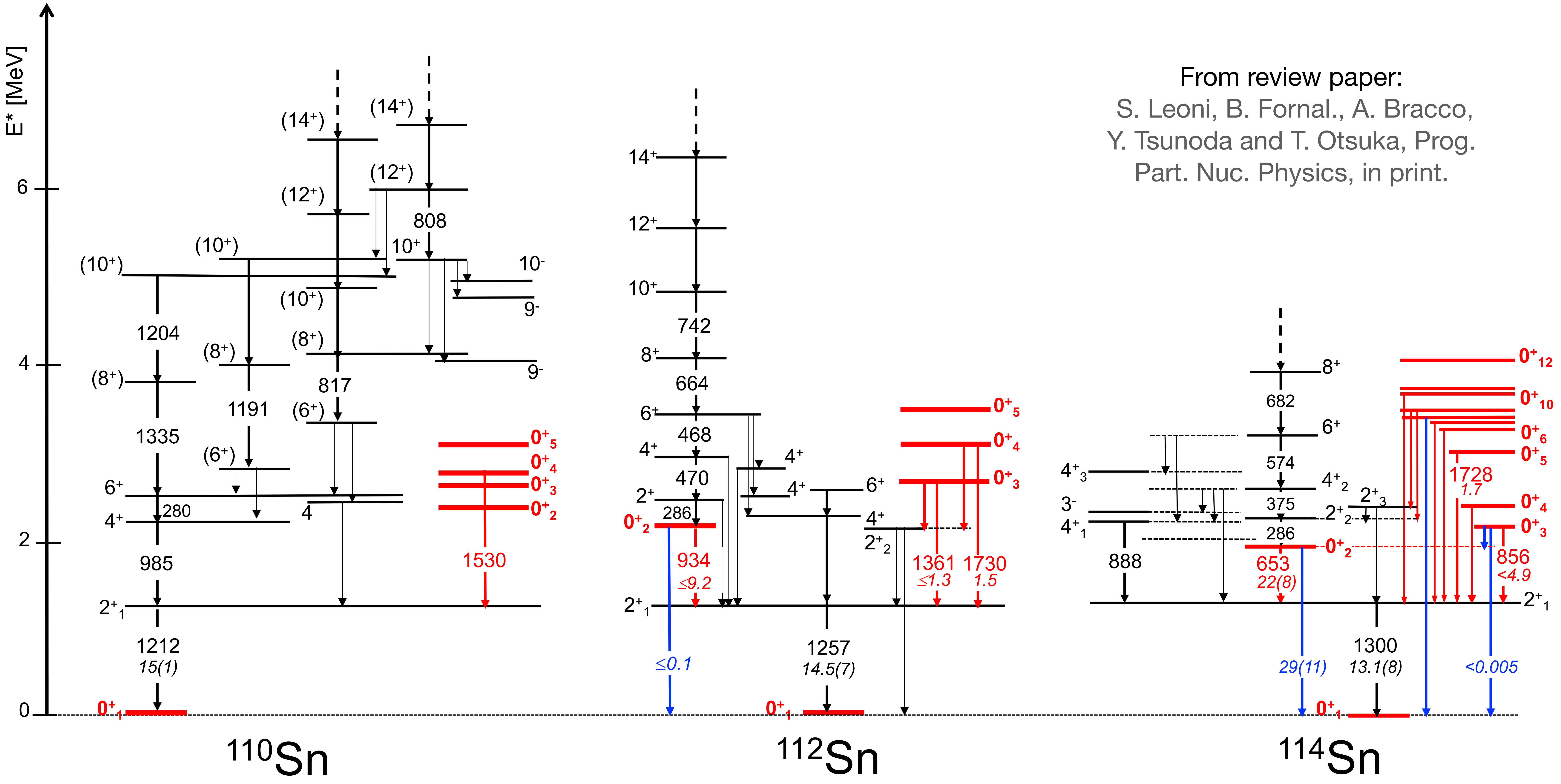


^{110}Sn

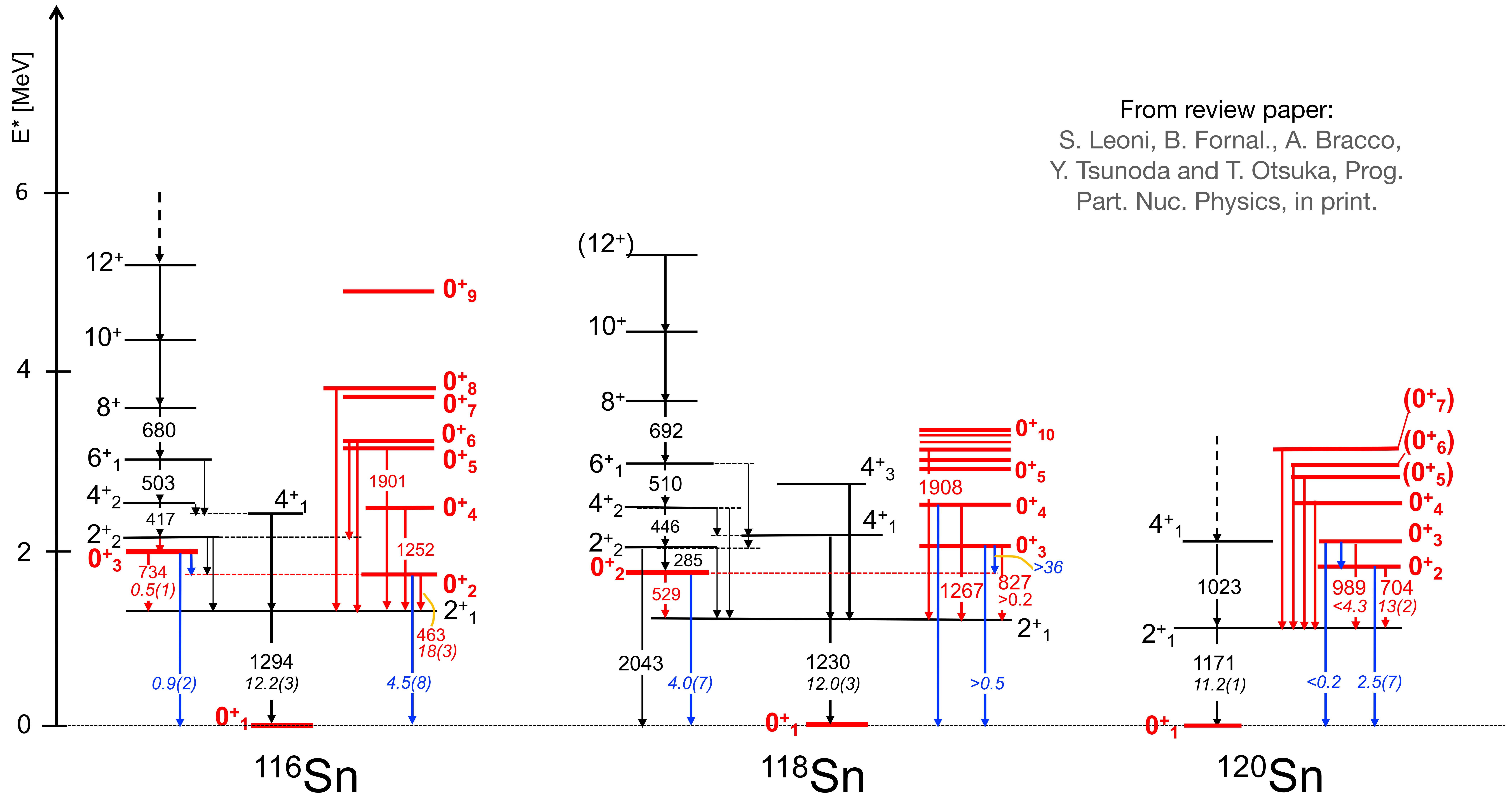


^{114}Sn

Backup - Level schemes $^{110\text{-}114}Sn$



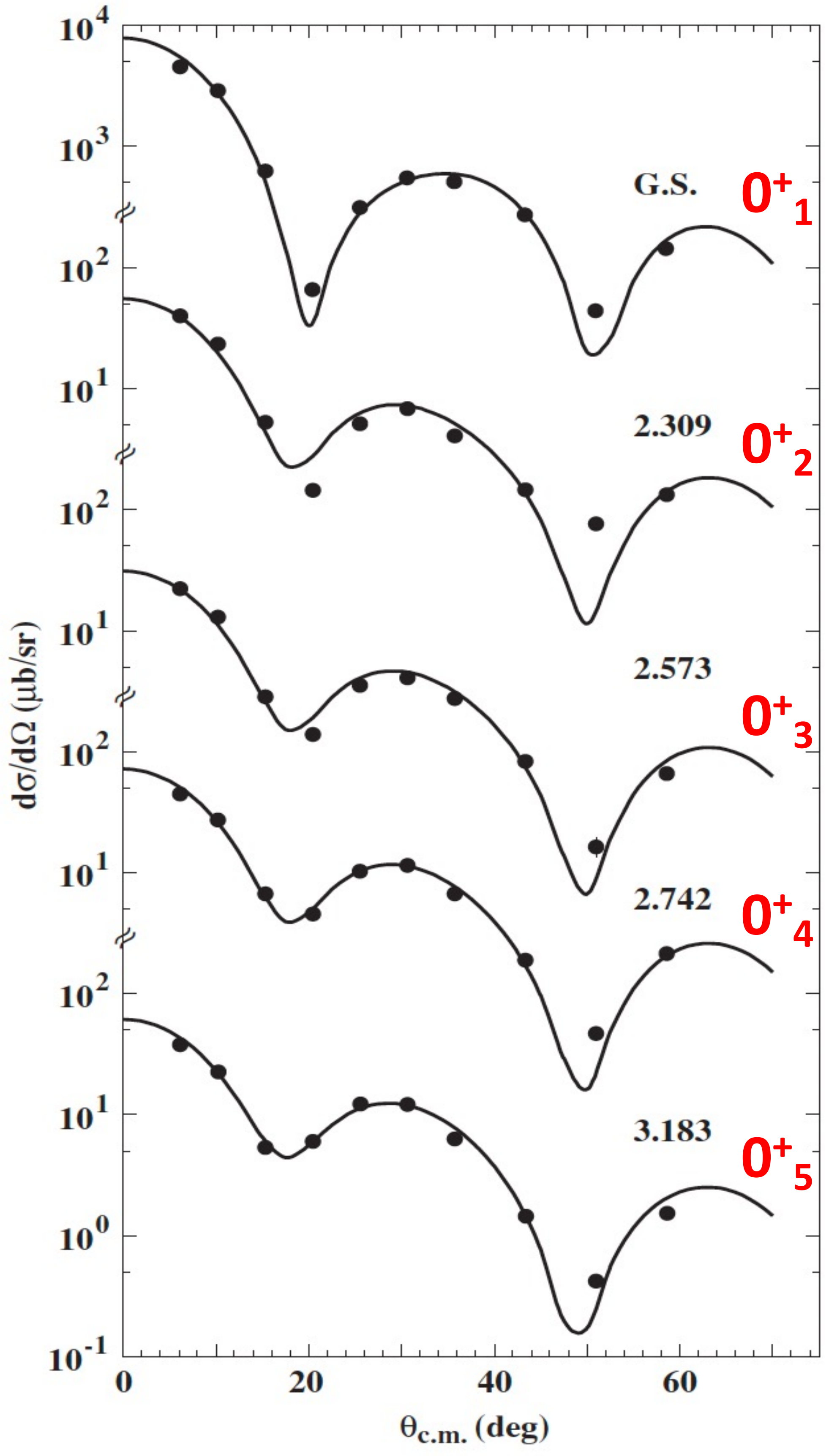
Backup - Level schemes $^{116-120}Sn$



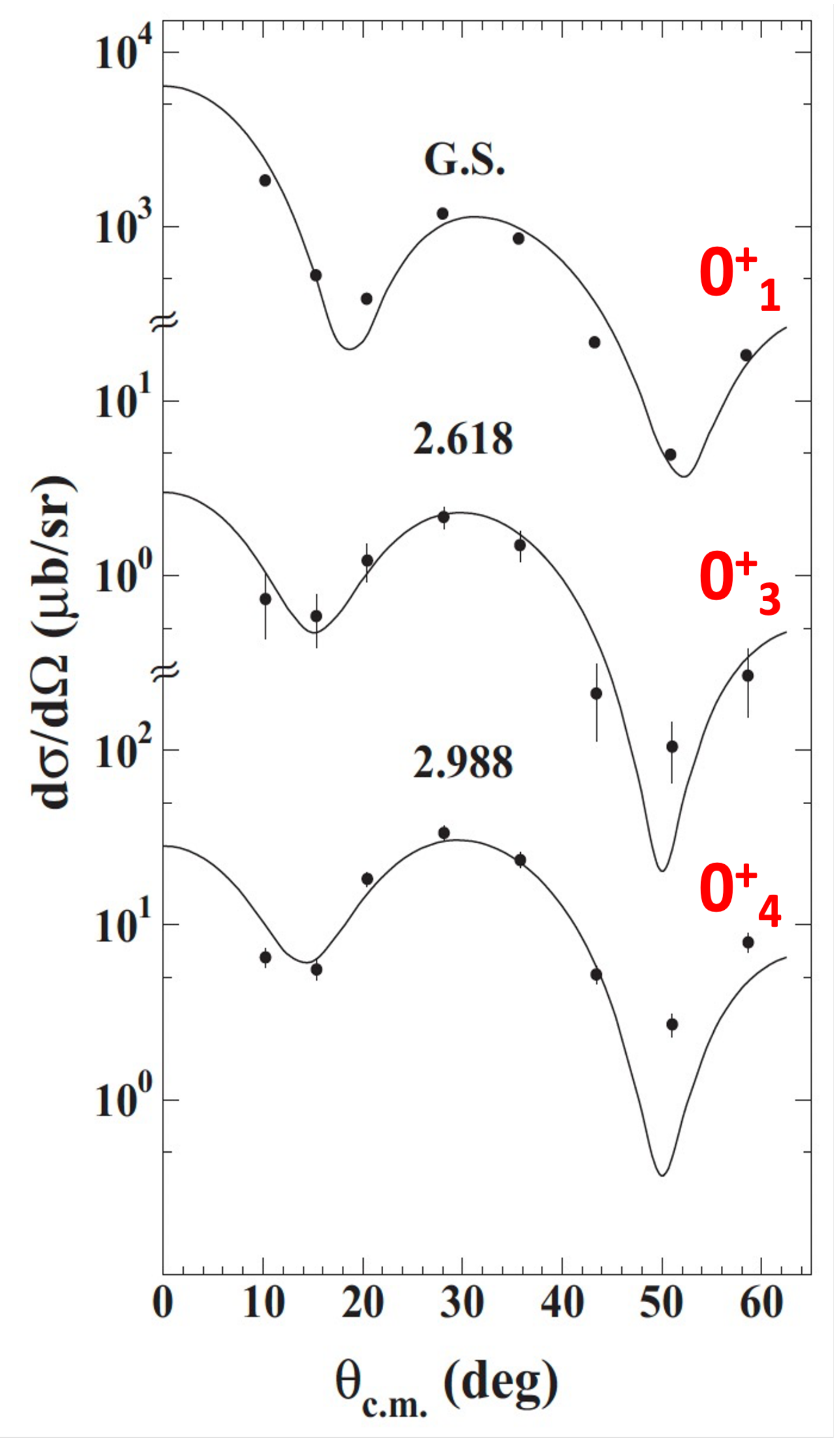
From review paper:
S. Leoni, B. Fornal., A. Bracco,
Y. Tsunoda and T. Otsuka, Prog.
Part. Nuc. Physics, in print.

Backup - (p,t) reactions

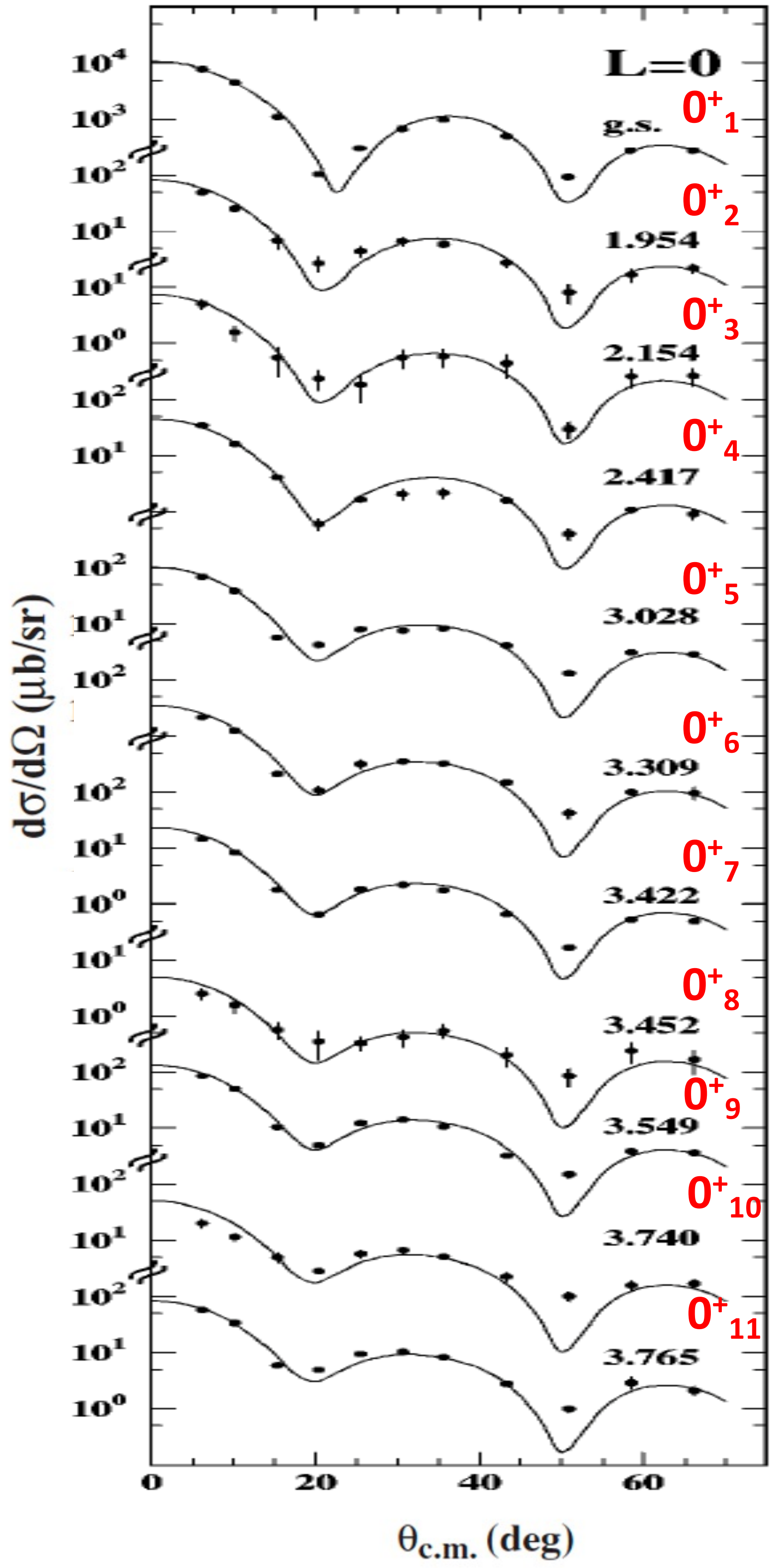
^{110}Sn



^{112}Sn



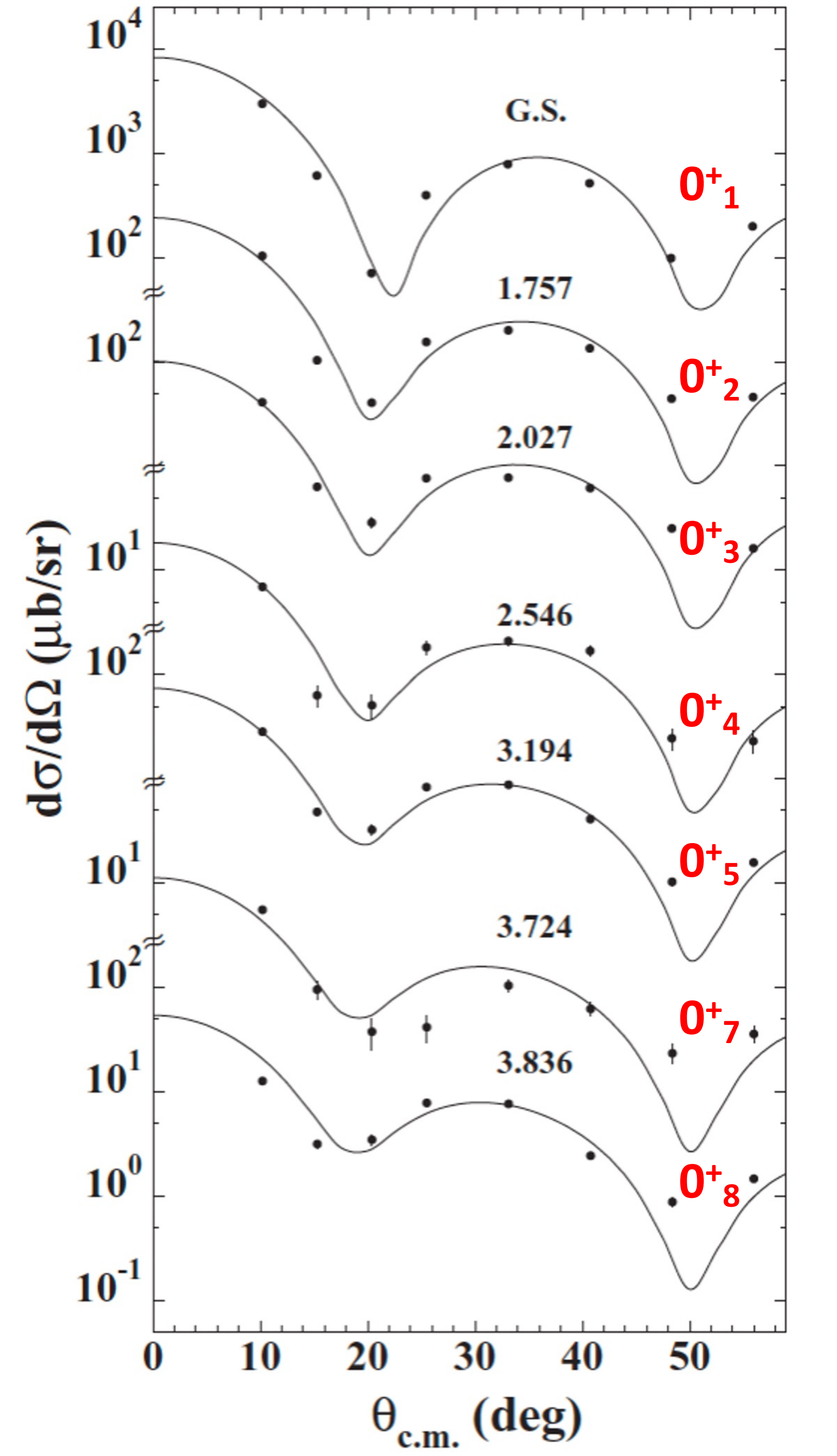
^{114}Sn



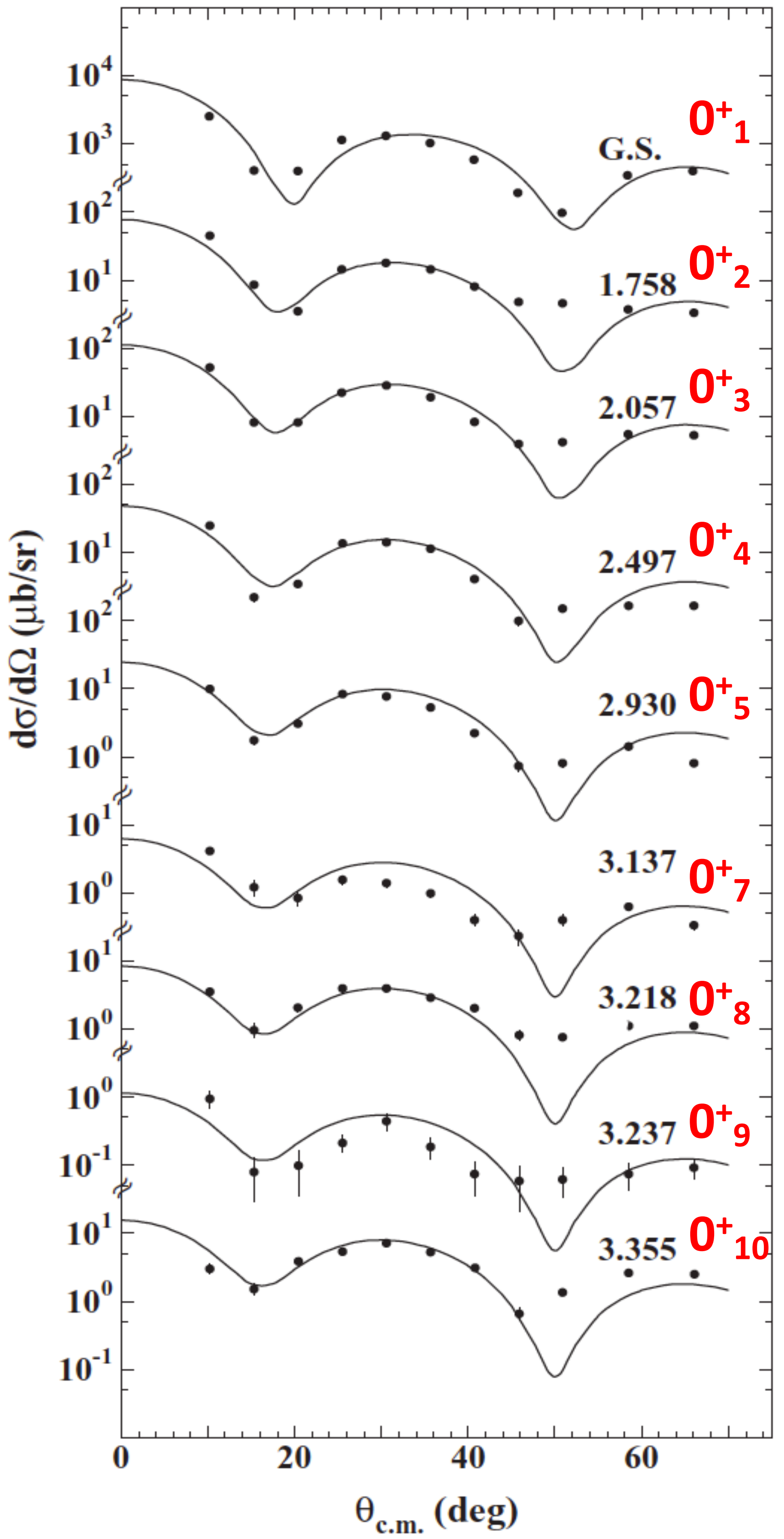
From review paper:
S. Leoni, B. Fornal., A. Bracco, Y. Tsunoda and T. Otsuka, Prog. Part. Nuc. Physics, in print.

Backup - (p,t) reactions

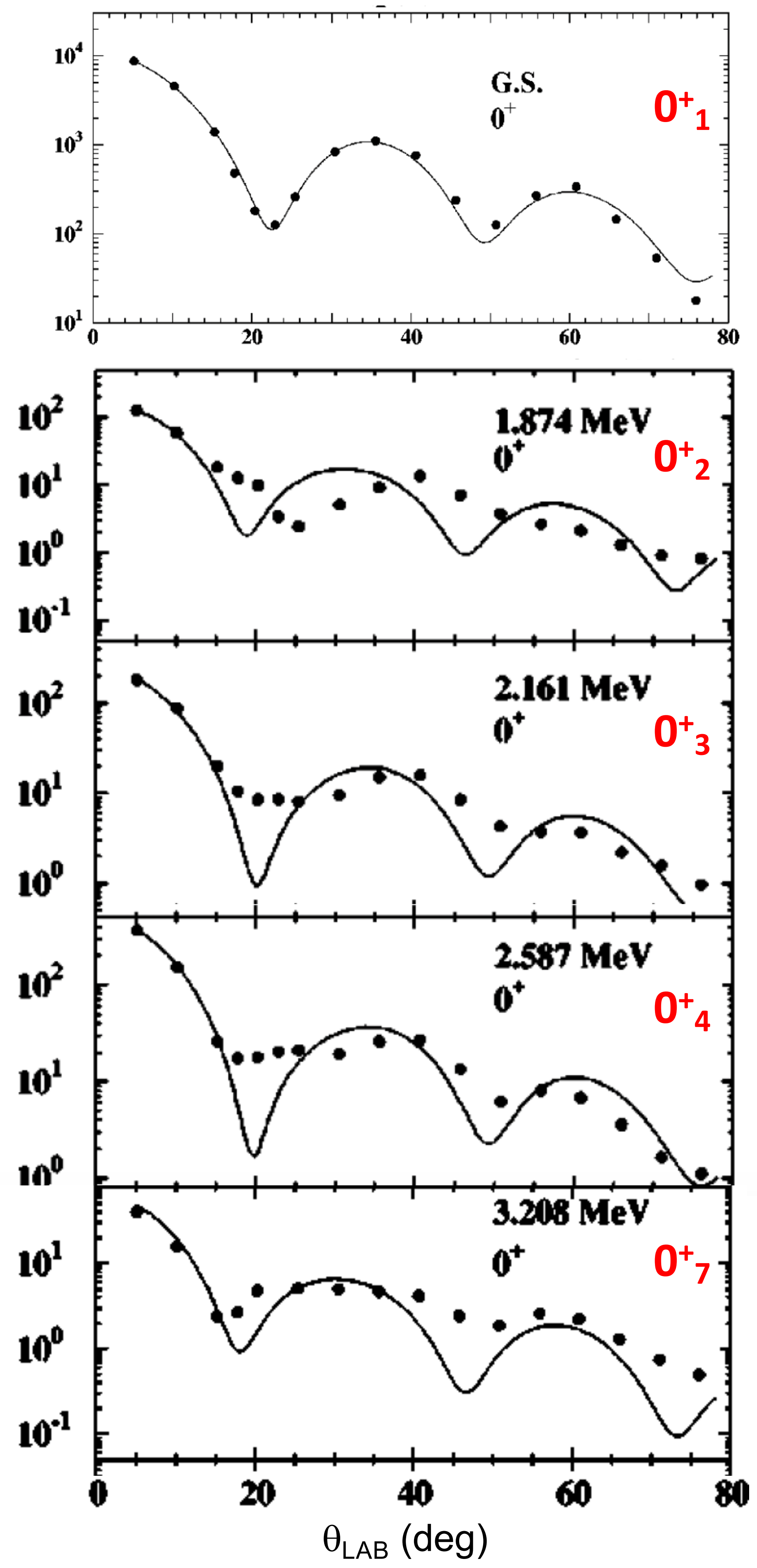
^{116}Sn



^{118}Sn



^{120}Sn



From review paper:
S. Leoni, B. Fornal., A. Bracco, Y. Tsunoda and T. Otsuka, Prog. Part. Nuc. Physics, in print.