Spectroscopy of ^{100}In with neutron knockout reactions

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High-resolution γ-ray spectroscopy at the RIBF Workshop

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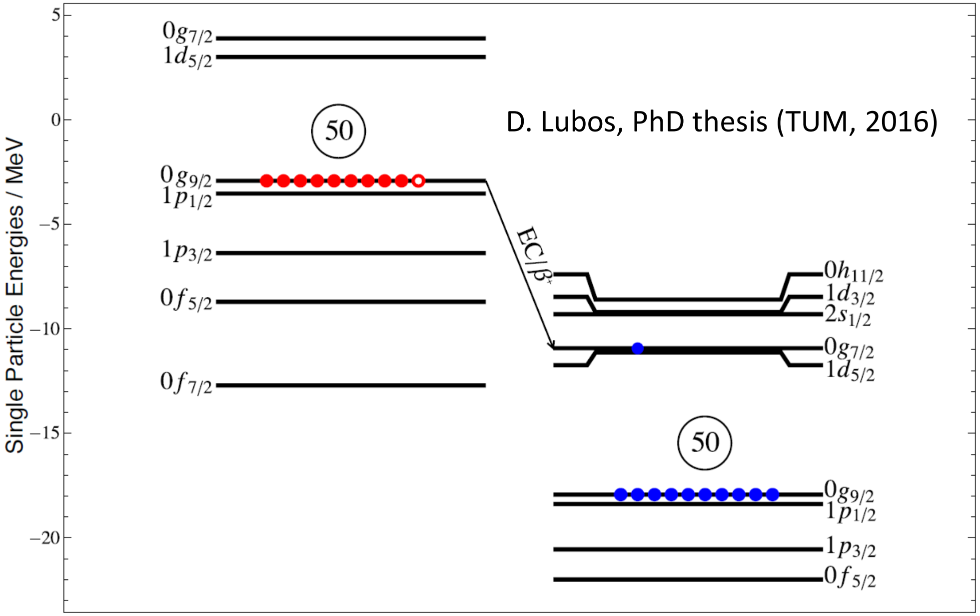
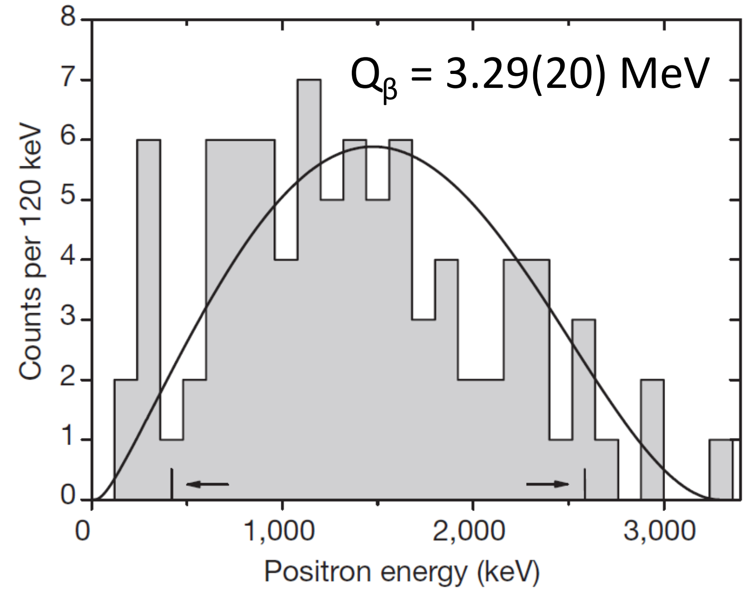
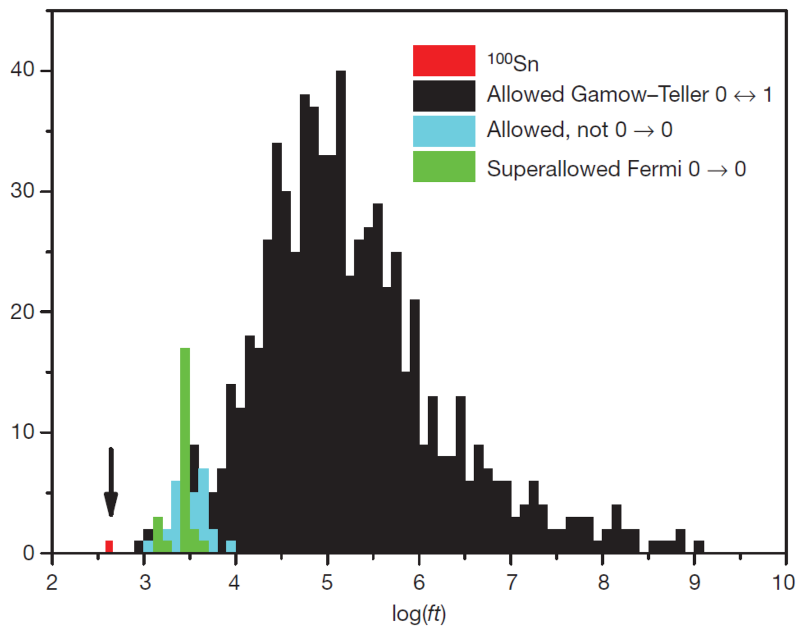
LUND UNIVERSITY

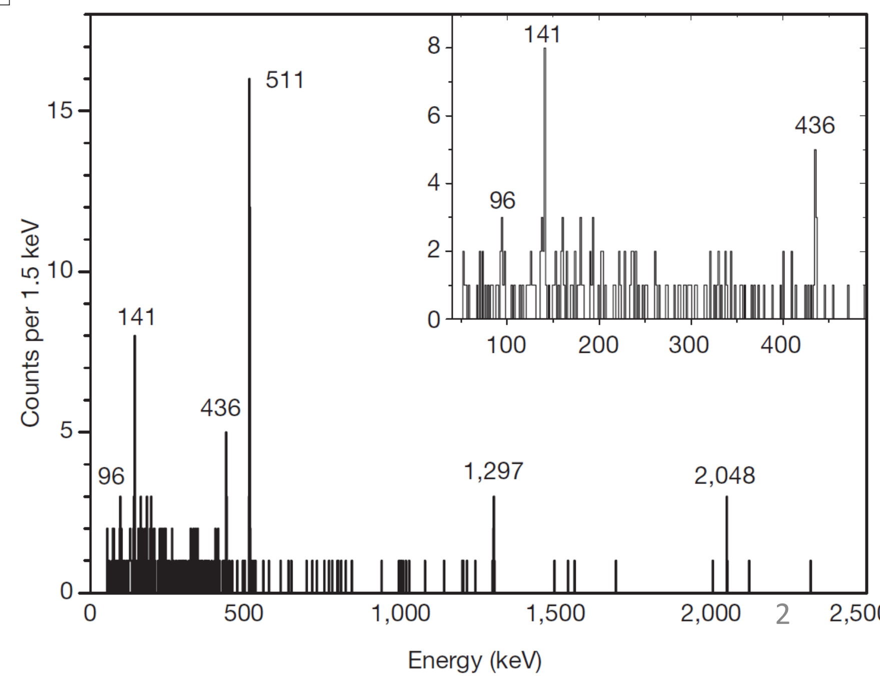
Gamow-Teller decay of ^{100}Sn



C. B. Hinke et al., Nature 486, 341 (2012)

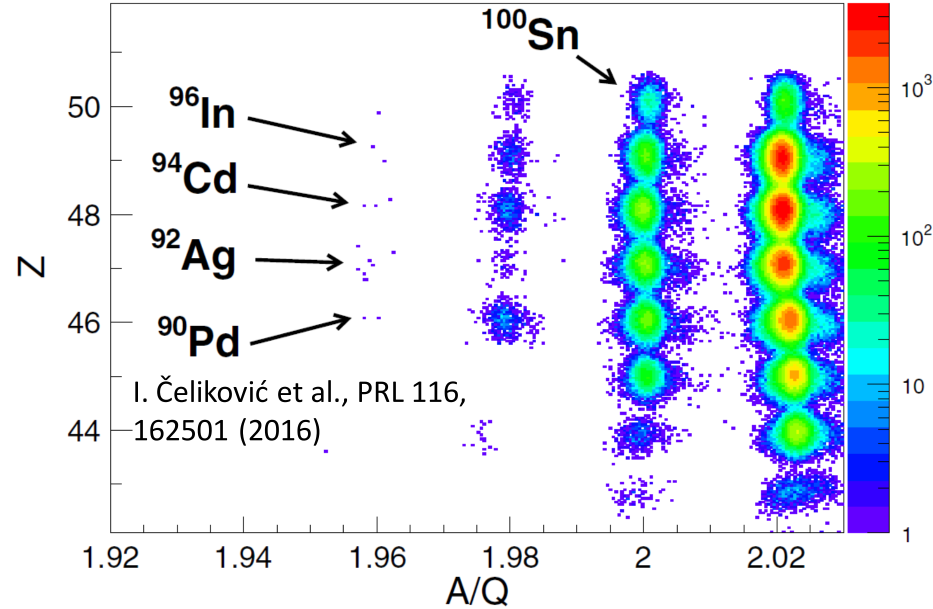




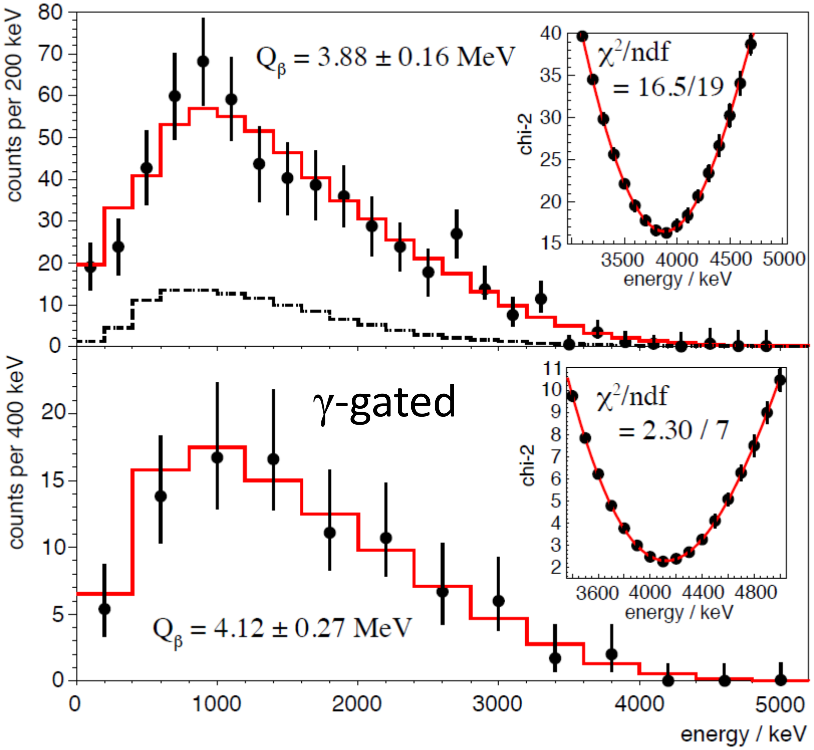


RIBF9 experiment

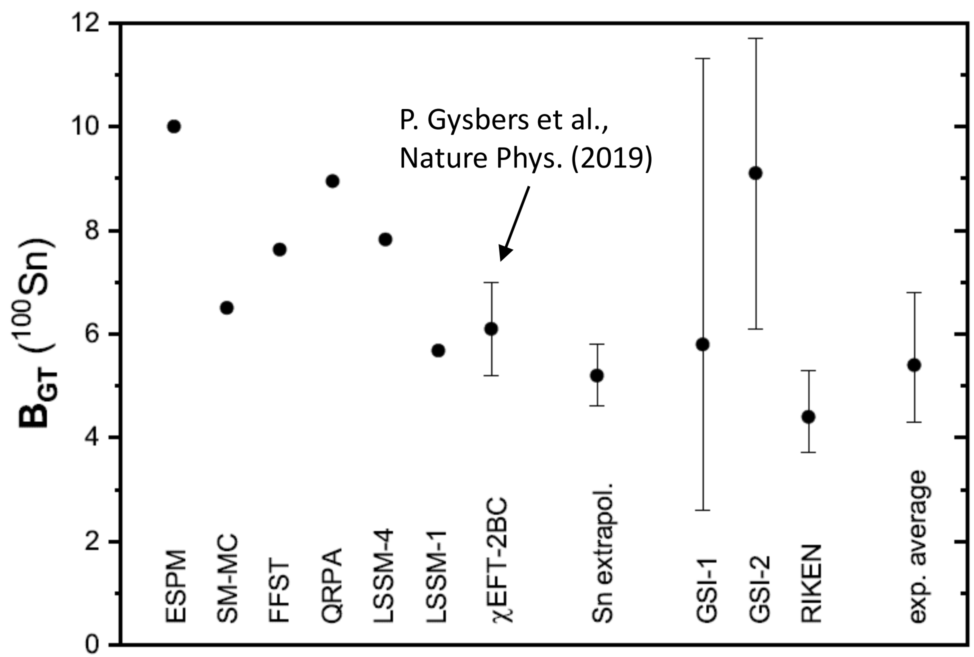
- WAS3ABi + EURICA in 2013
- Average ^{124}Xe rate: 20 pnA, 200 hours
- ~2500 ^{100}Sn produced, × 10 in statistics
- New isotopes identified



D. Lubos et al., PRL (submitted)



$B_{GT}(^{100}Sn)$: $5.8^{+5.5}_{-3.2}$(GSI-1), $9.1^{+3.0}_{-2.6}$(GSI-2), $4.4^{+0.9}_{-0.7}$(RIKEN)



βγ spectroscopy of ^{100}In from RIBF9

Reduced EURICA efficiency:
4.6% at 1 MeV (with addback)

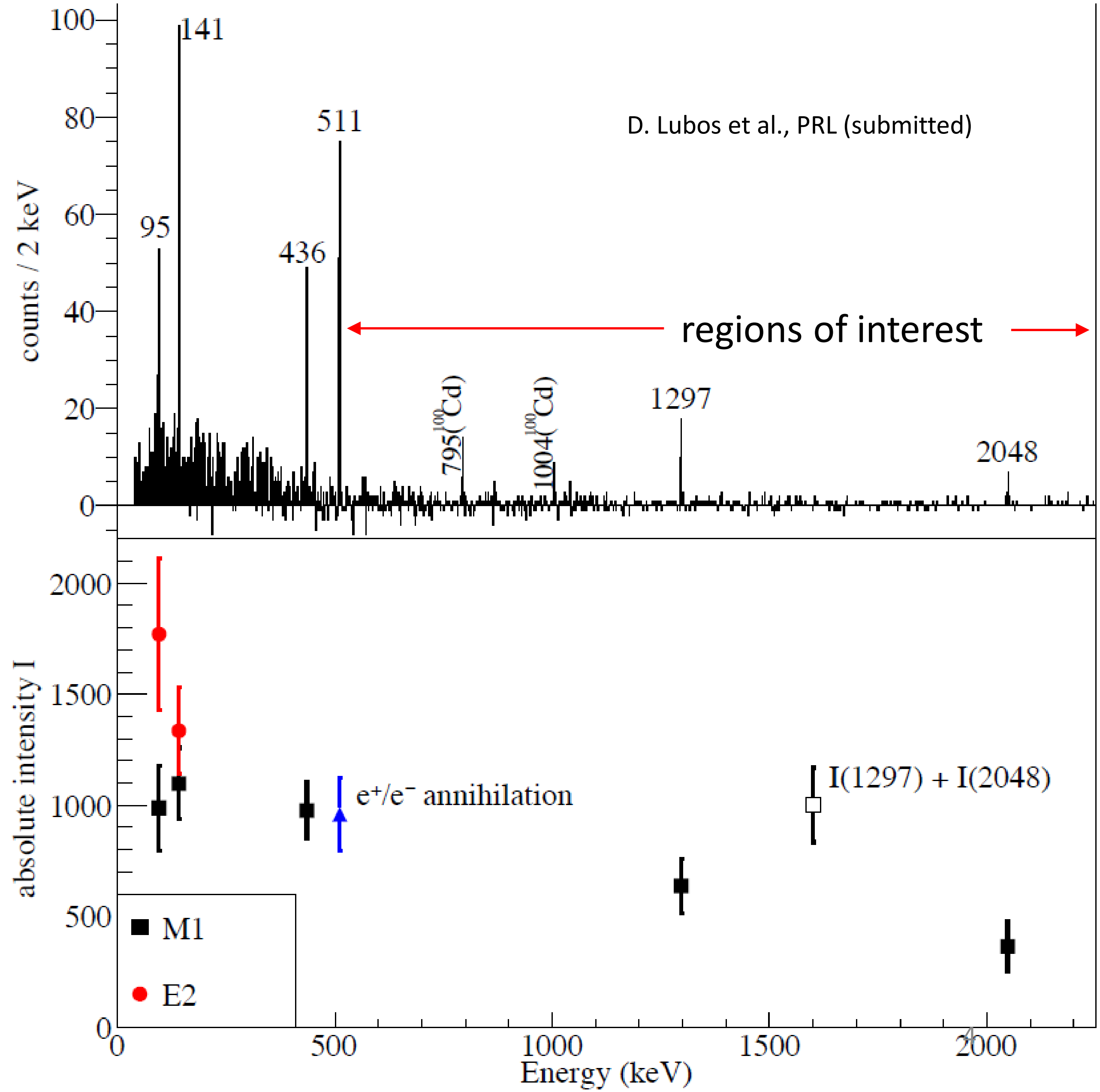
γγ coincidence relations:

- 95-141-436 pairwise
- 141-1297
- 95-2048 (1 count)

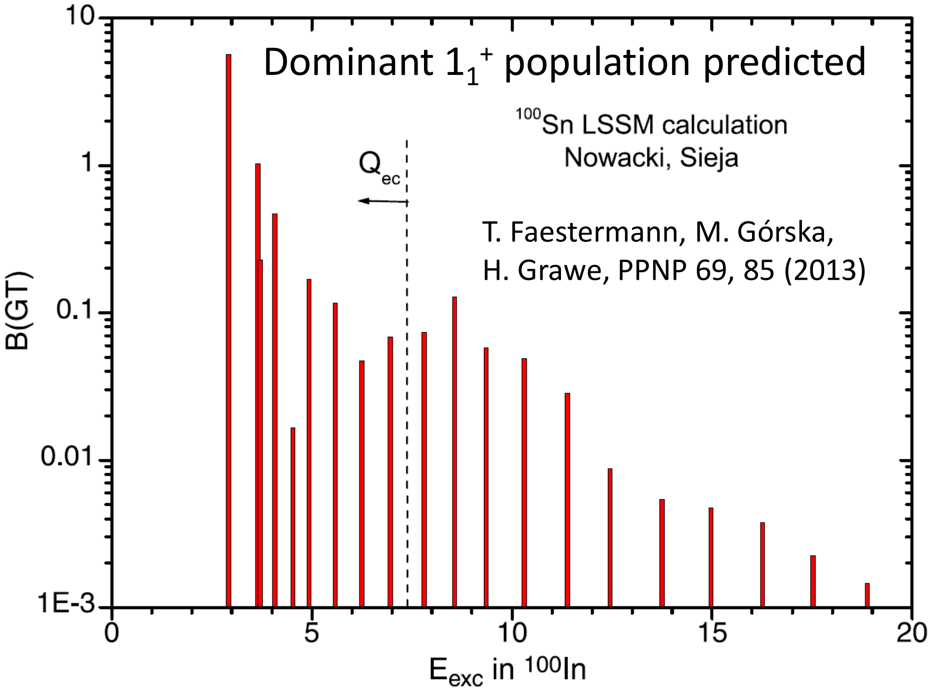
95, 141-keV γ's likely M1, not delayed

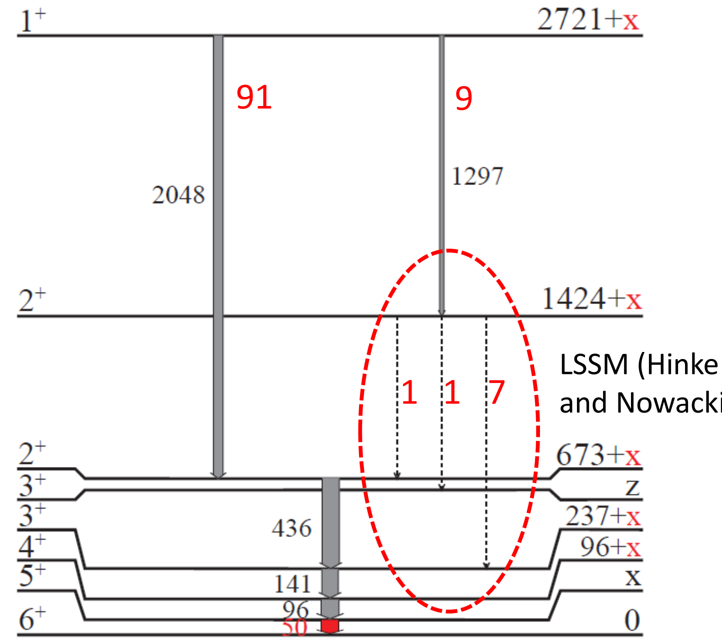
1297, 2048-keV parallel branches?

Not much room (< 15%) for feeding into other states

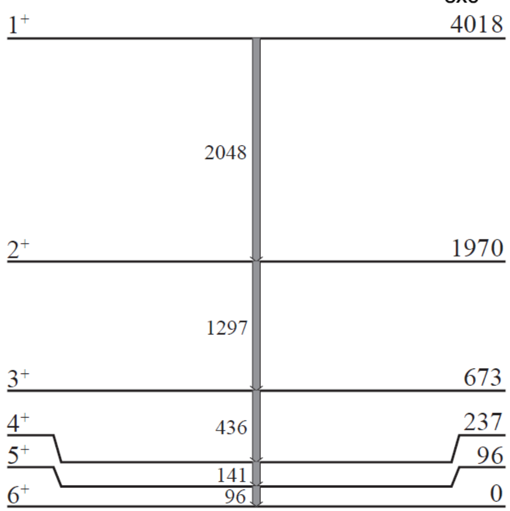


SM calculations of $^{100}Sn \rightarrow {}^{100}In$ decay, levels



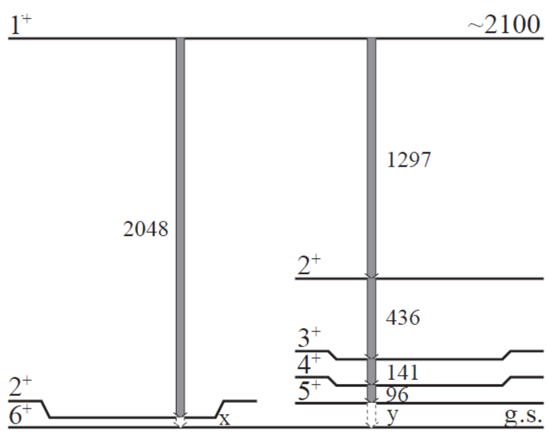


(d) Experiment



(a) Stone and Walter

D. Lubos, PhD thesis (TUM, 2016)



(b) Coraggio

Unobserved γ-ray energies:
751, 800-1100, 1187 keV
Compared to I ± δI (1297 keV) and
I(1297)/I(2048), growing concerns

$5^+ \rightarrow 6^+$: 30 ± 30 keV assumed

$Q_{EC}(^{100}Sn)$ = 7.03(24) MeV (AME2016),
6.9(10) MeV (PRL 77, 2400 (1996))
This work: 7.69(16) MeV

Spectroscopy on ^{100}In

Objectives:

- Attain a more complete low-spin, low-energy level scheme of ^{100}In: precise gauge of systematic uncertainties on ^{100}Sn B_{GT}
- Fix the yrast 1^+ state energy for Q_{EC}(^{100}Sn) and comparisons with SM
- Probe the single-particle structure of ^{100}In through in-beam γ-ray spectroscopy

Method: neutron knockout reactions on ^{101,102}In

Observables:

- Previously unobserved bridge transitions in ^{100}In, or confidence limits
- γ rays from higher 1^+ states in ^{100}In
- Lifetimes of yrast 3^+, 4^+, 5^+ states from 95/141/436-keV γ's → B(M1)
- 1n, 2n knockout cross sections to different states

Experiment proposal details

Primary beam: ^{124}Xe, 345 MeV/u, 80 pnA
Primary target: 4-mm Be

Secondary target: CH_2, 500 mg/cm^2 and C, 400 mg/cm^2
[similar to ^{104}Sn, ^{102}Cd 2n knockout with DALI2 by A. Corsi et al., 2018]

Secondary beam energies: ~150 MeV/u
Intensities at F8 from LISE++:

^{100}Sn 1.21e-8 0%	^{101}Sn 8.19e-2 8.366%	^{102}Sn 2.52e+1 47.028%	^{103}Sn 2.17e+1 1.151%
^{99}In 4.18e-7 0%	^{100}In 1.21e+1 5.687%	^{101}In 2.48e+3 57.418%	^{102}In 5.15e+3 6.387%
^{98}Cd 1.17e-4 0%	^{99}Cd 1.17e+2 0.706%	^{100}Cd 8.92e+4 50.86%	^{101}Cd 1.75e+5 8.981%
^{97}Ag	^{98}Ag 7.94e+1 0.018%	^{99}Ag 4.02e+5 8.076%	^{100}Ag 3.46e+5 1.311%

Optimized for ^{101}In

^{100}Sn 4.92e-8 0%	^{101}Sn 5.29e-7 0%	^{102}Sn 4.42e+0 8.254%	^{103}Sn 8.98e+2 47.587%
^{99}In 6.27e-5 0.001%	^{100}In 2.55e-5 0%	^{101}In 2.84e+2 6.579%	^{102}In 4.64e+4 57.565%
^{98}Cd 4.2e-3 0.001%	^{99}Cd 3.72e-3 0%	^{100}Cd 1.71e+3 0.973%	^{101}Cd 1.02e+6 52.123%
^{97}Ag 3.12e-3 0%	^{98}Ag	^{99}Ag 1.69e+3 0.034%	^{100}Ag 2.51e+6 9.501%

Optimized for ^{102}In

- Need to suppress Cd, Ag
- ^{102}In perhaps too intense for BigRIPS + ZeroDegree

BigRIPS + ZeroDegree PID trigger

Yield estimates

Beam time: 3 days (72 hours) on CH_2, 2 days on C targets
Secondary beam intensities at F8, centered on ^{101}In:

- ^{101}In: 2.48×10^3 pps
- ^{102}In: 5.15×10^3 pps

Secondary target: CH_2, 500 mg/cm^2
Transmission through ZeroDegree: 57-58%
PID, operation efficiency: 70%

Neutron knockout cross sections into excited states in ^{100}In:

- 1 mb for 1n knockout [0.8-2.3 mb in ^{70}Kr (K. Wimmer)]
- 0.1 mb for 2n knockout [0.5(2), 1.4(9) mb for 2^+ states in ^{102}Sn (A. Corsi), 0.04-0.08 mb in ^{70}Kr (K. Wimmer)]

Median HPGe array efficiency: 5% (search range: 500-3000 keV)
Expected γ-ray counts assuming 100% branch:

- 600 from 1n knockout on ^{101}In
- 130 from 2n knockout on ^{102}In

→ ~10 increase in statistics; 3γ coincidences

On shielding/mass measurements, ^{99}In

If atomic background is huge, then Pb + Sn shielding is necessary

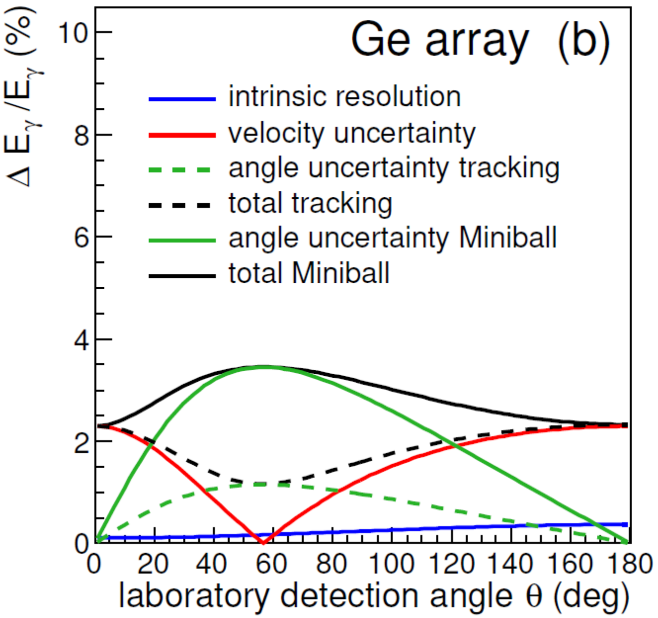
- Reduced efficiency for < 150-keV γ's; search for $5^+ \rightarrow 6^+$ more difficult
- Intensity and $\gamma\gamma$ coincidence analysis with 436/1297-keV γ's
- Main search region above 500 keV, less background

If shielding is not needed:

- Energy resolution at ~100 keV?
- Lifetime measurements for 95/141-keV γ's?

Mass measurements at F11:

- $Q_{EC}(^{100}In)$ = 9.88(18) MeV (decay spectroscopy)
- $Q_{EC}(^{101}In)$ = 7.22(20)* MeV (AME2016 extrapolation)



(Construction proposal, 1 MeV γ)

^{99}In from 2n knockout of ^{101}In:

About 1500 reactions expected, one excited state from $p_{1/2}$ proton hole (S_p ~ 1 MeV);
γ-ray from $1/2^-$ isomer?