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UNIVERSITY of GUELPH

ISOLDE Decay Station

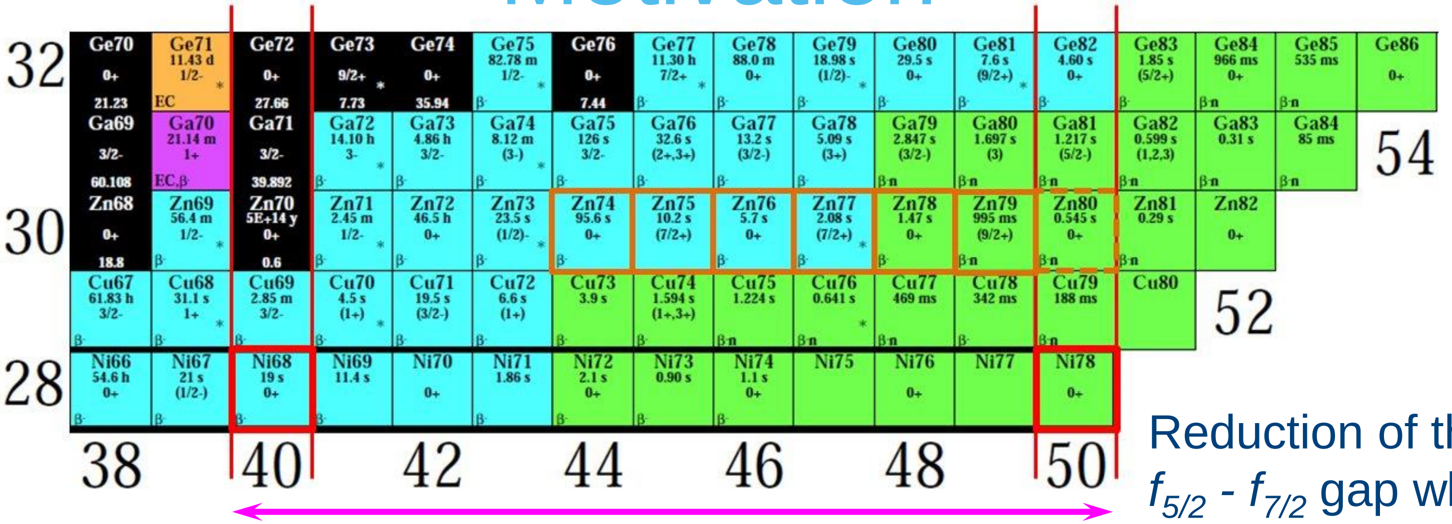
Cu decay into neutron-rich Zn isotopes: shell structure near ^{78}Ni

Spokepersons:

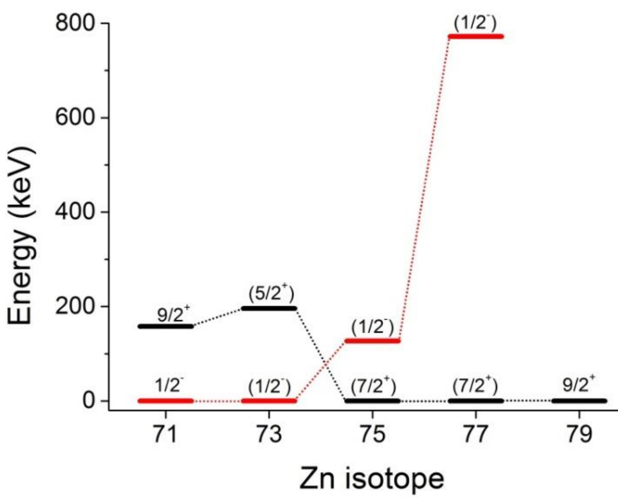
A. Illana Sison (KU Leuven)

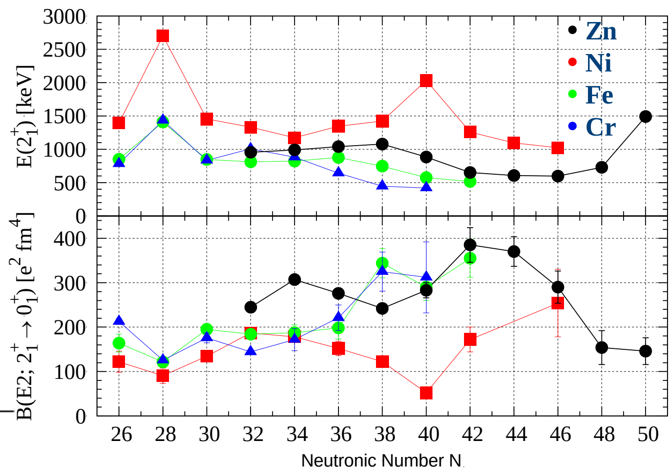
B. Olaizola Mampaso (UoGuelph)

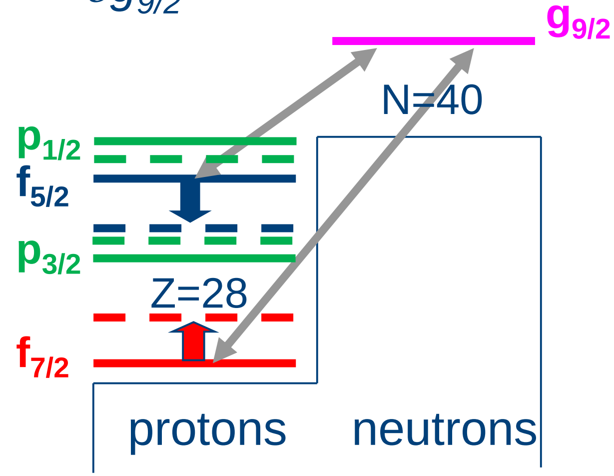
Motivation



Reduction of the proton $f_{5/2}$ - $f_{7/2}$ gap when filling $\upsilon g_{9/2}$

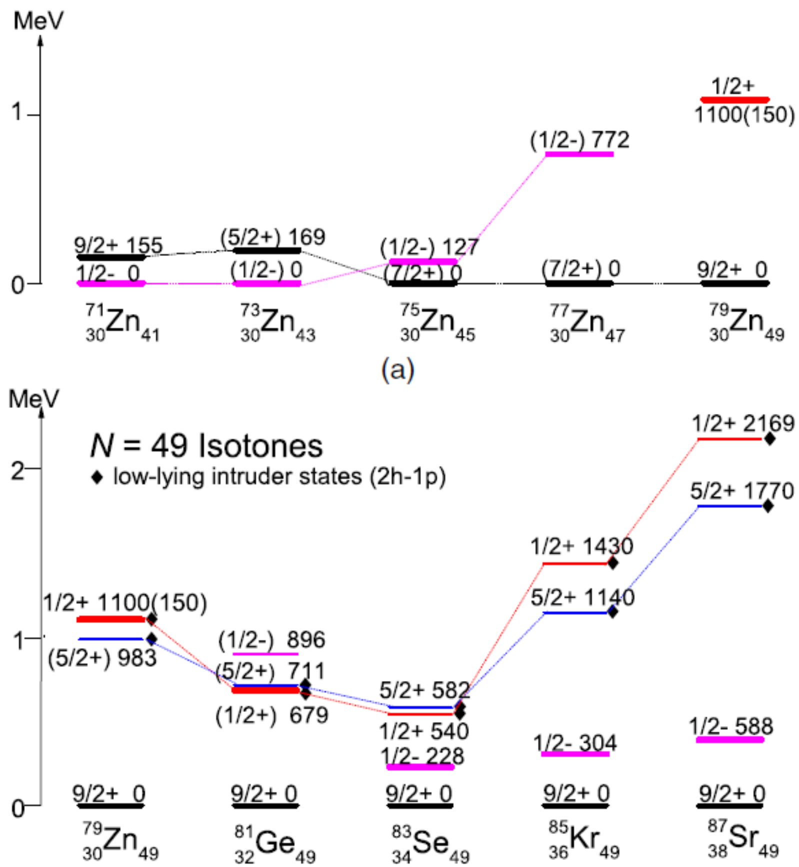






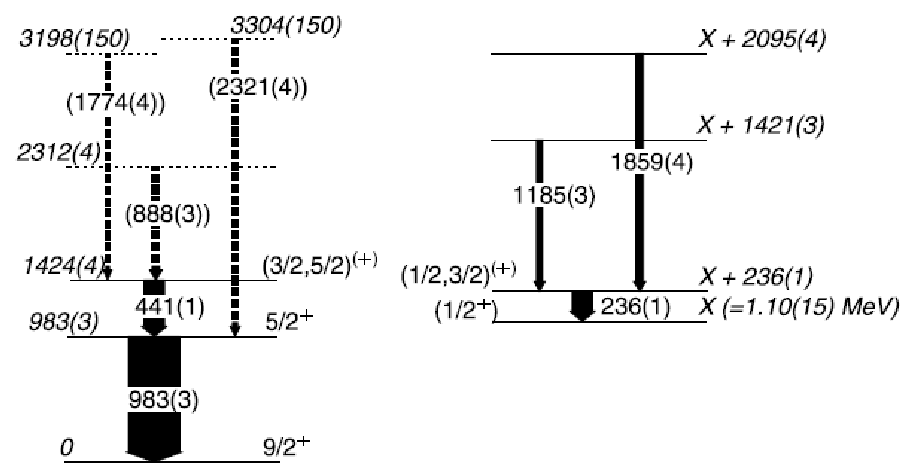
T. Otsuka et al., Phys. Rev. Lett. 95, 232502 (2005)

Physic case for the odd-even Zn



What we want to study:

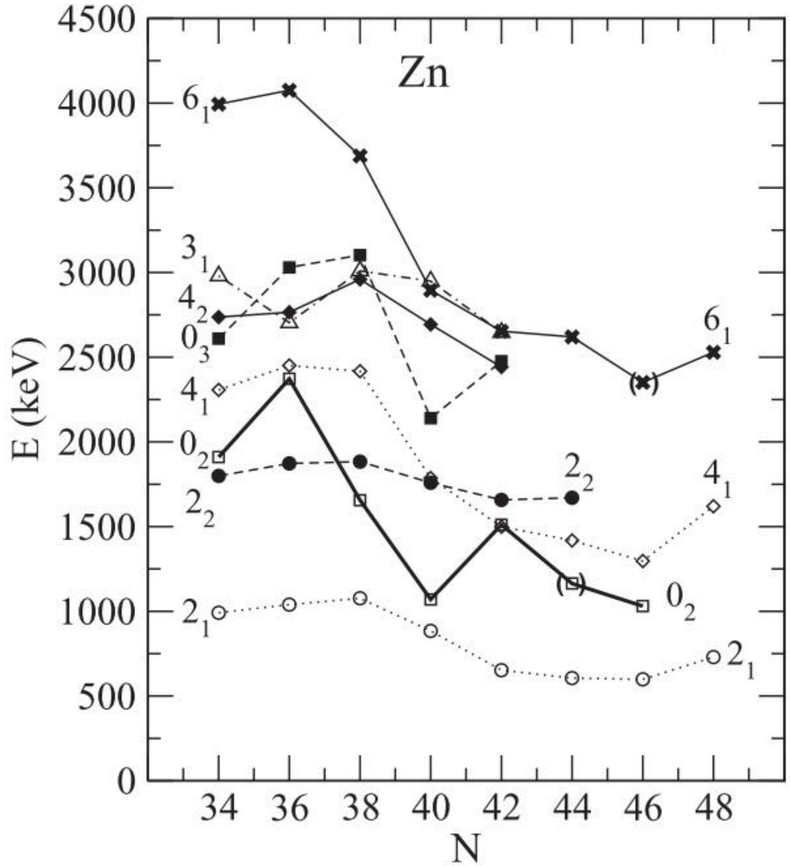
- No information about B(M1) and B(E2) in the ^{75,77,79}Zn nuclei. Essential constrains for SM calculations.
- Level scheme for ^{79}Zn was observed in a (d,p) reaction.
- Isomeric state in ^{79}Zn needs more study. This state hinted to shape coexistence.

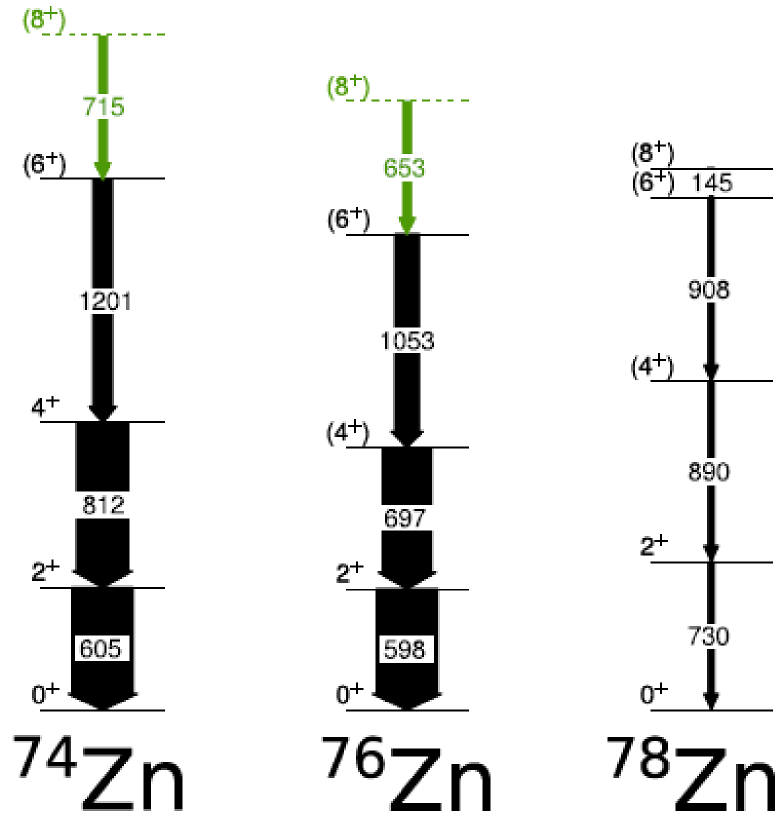


R. Orlandi et al., Phys. Lett. B 740, 298-302(2015)
X.F. Yang et al., Phys. Rev. Lett. 116, 182502(2016)

Physic case for the even-even Zn

A lot of information in the level scheme for the most neutron-rich Zn isotopes is still missed





M. Niikura et al., Phys. Rev. C 85, 054321(2012)
P.R. John. PhD Thesis (2015)

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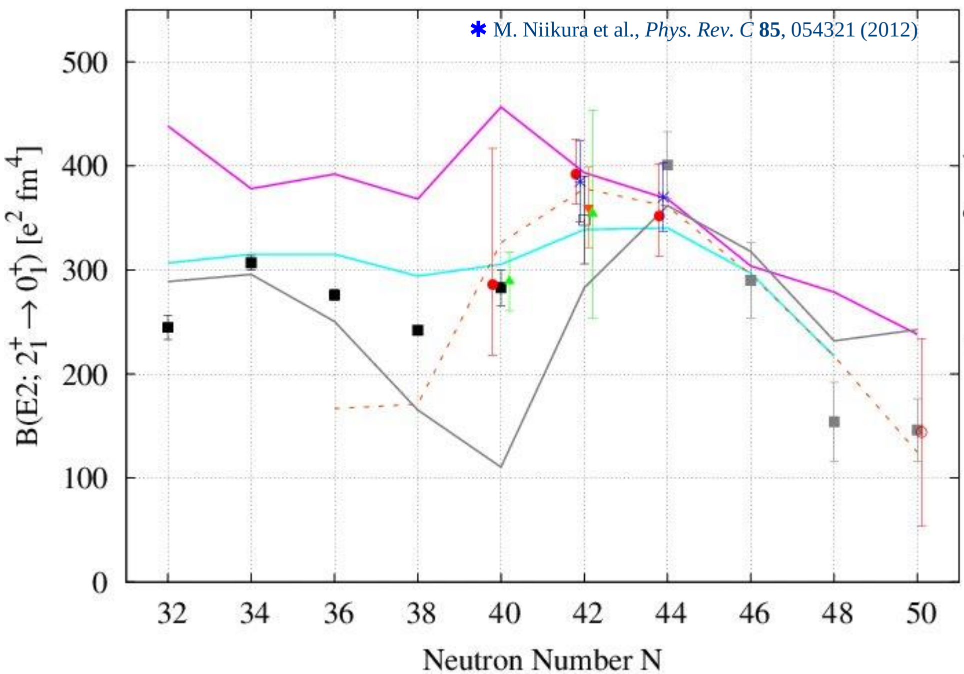
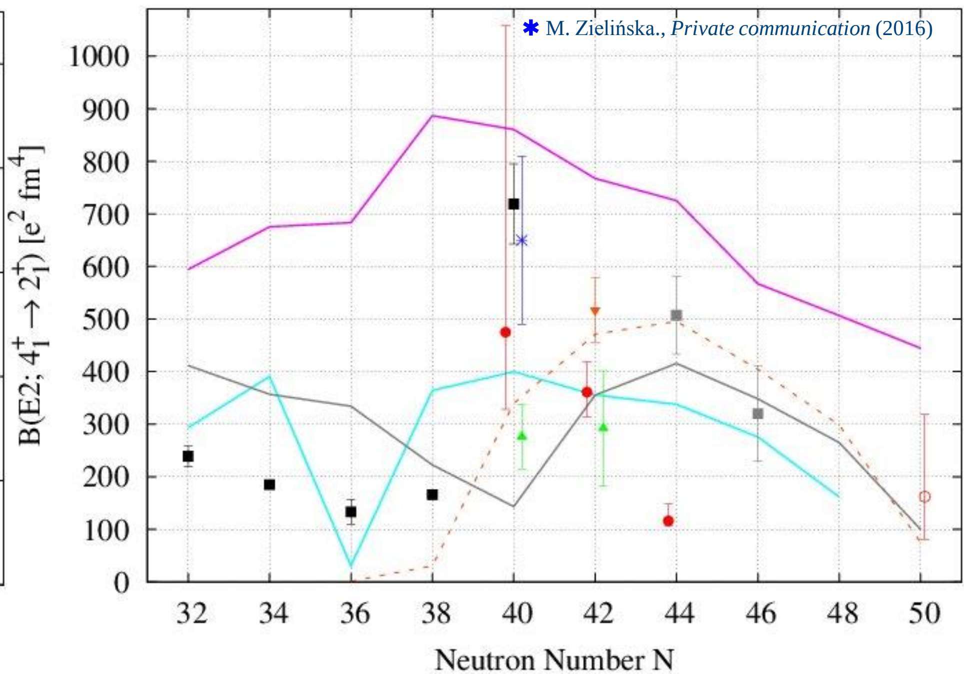
Physic case for the even-even Zn





New inputs are needed!

- ■ National Nuclear Data Center (NNDC). DSAM experiments.
- ■ J. Van de Walle et al., *Phys. Rev.* C **79**, 014309 (2009) - Coulex experiment
- ● C. Louchart et al., *Phys. Rev. C* **87**, 054302 (2013)
- ▲ I. Čeliković et al., *Act. Phys. Pol. B* **44**, 375-380 (2013)
- ▼ S. Hellgartner, PhD Thesis, TU Munich (2015)
- ○ Y. Shiga et al., *Phys. Rev. C* **93**, 024320 (2016)
- — M. Honma et al., *Phys. Rev. C* **80**, 064323 (2009)
- ... S. Lenzi et al., *Phys. Rev. C* **82**, 054301 (2010)
- — J.-P. Delaroche et al., *Phys. Rev. C* **81**, 014303 (2010)
- — T. Osuka., *Private communication* (2016)

In ^{74}Zn → Huge discrepancy between RDS and COULEX experiments. It changes the interpretation in the region.
No lifetime measurements for ^{76,78}Zn.
Independent and reliable inputs are essential for the COULEX calculations. *IS557 First HIE-ISOLDE experiment*

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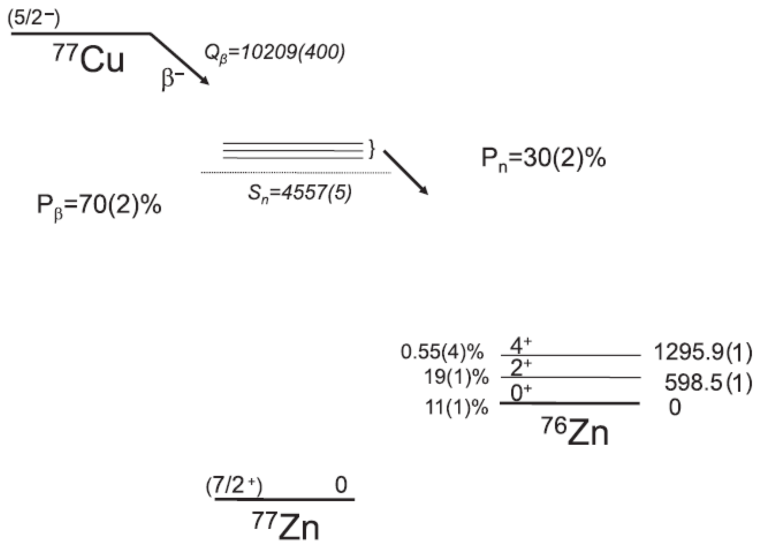
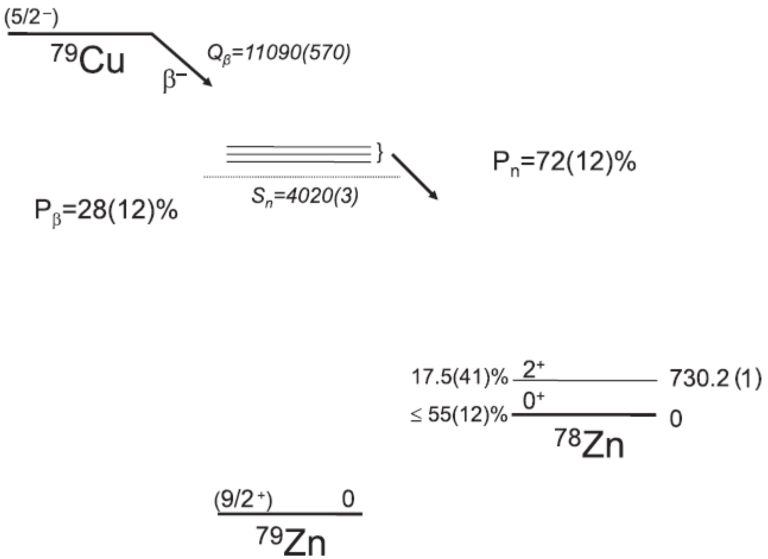
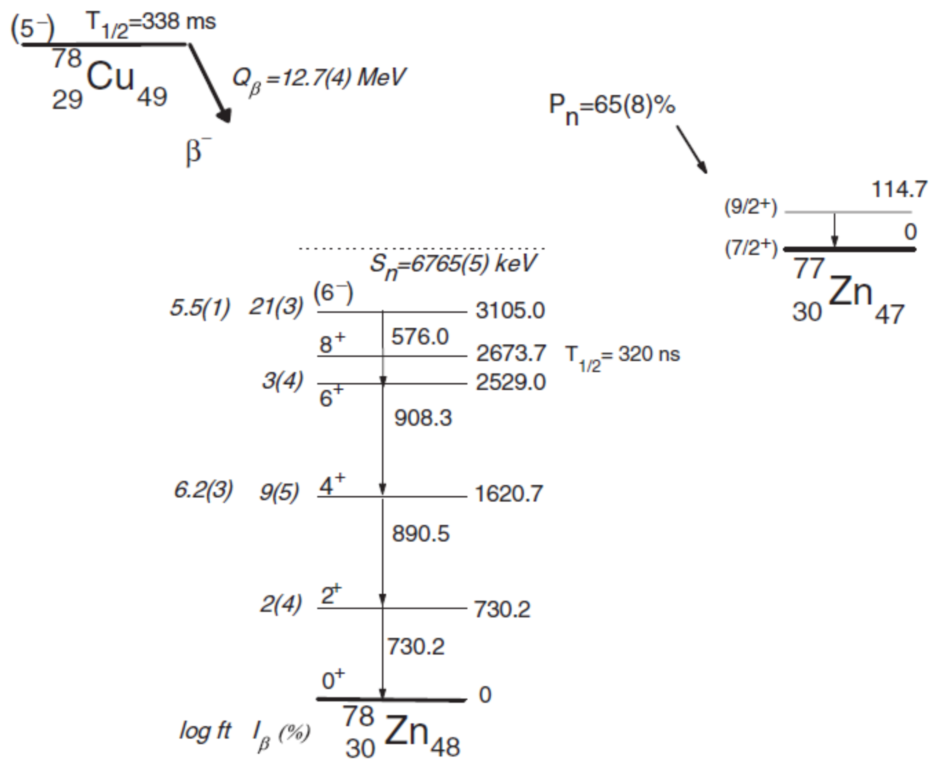
The influence of the βn branch





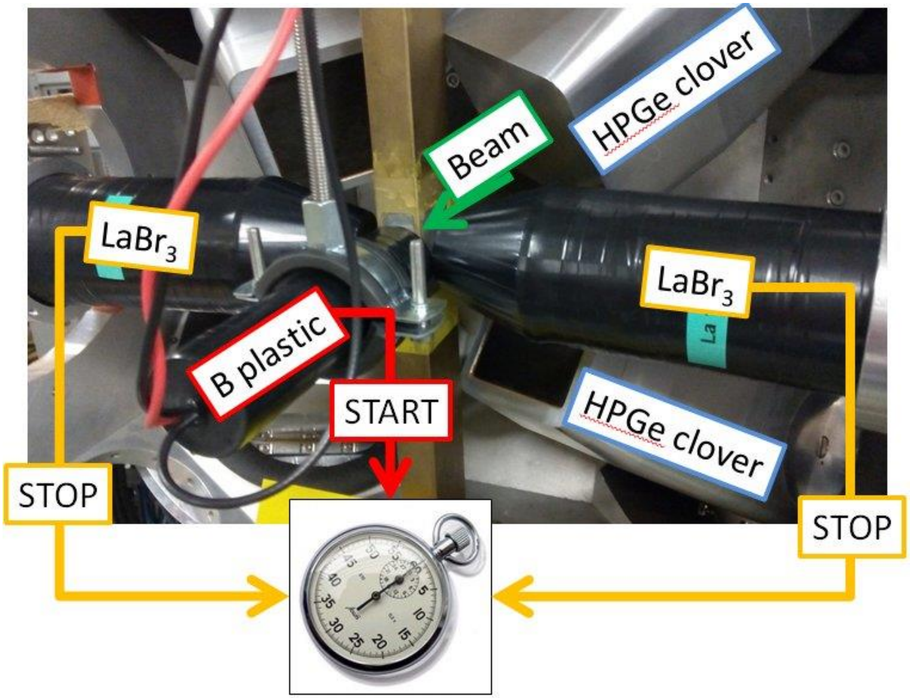


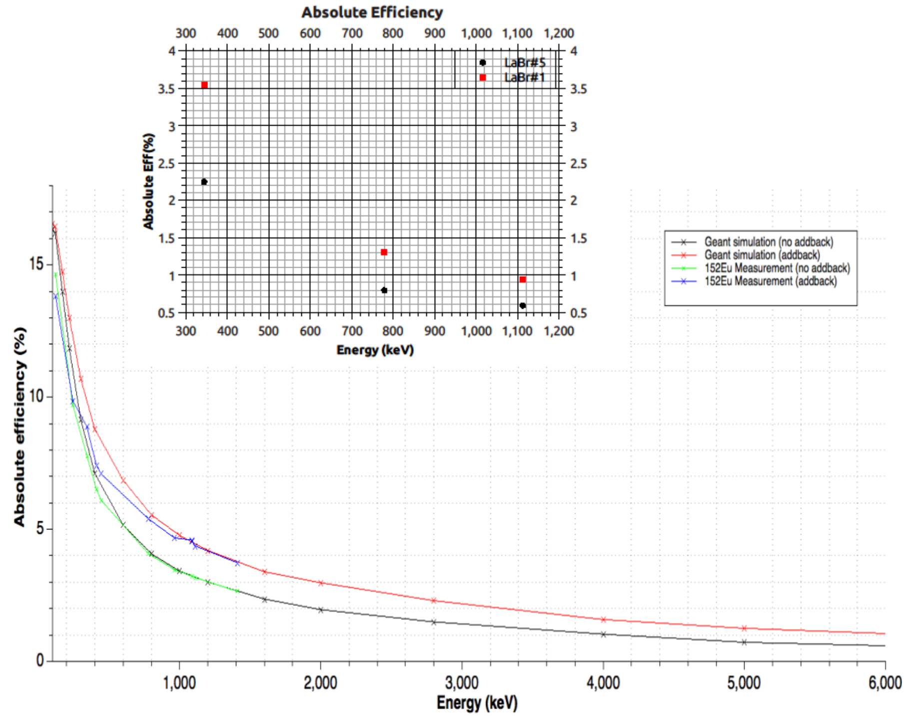
^{80}**Cu:** ***Pn*** **~ 60(20) %**

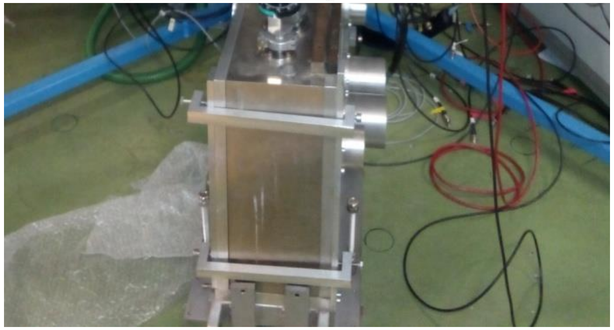
Huge impact in the theoretical models.
High astrophysical importance.

A. Korgul et al., Phys. Rev. C 86, 024307(2012)
Z.Y. Xu, PhD Thesis (2014)

The setup







Similar setup that this year:

- **4 HPGe clovers**
- **2 LaBr$_3$ scintillators. (Timing resolution ~ 120 ps)**
- **1 beta plastic scintillator**

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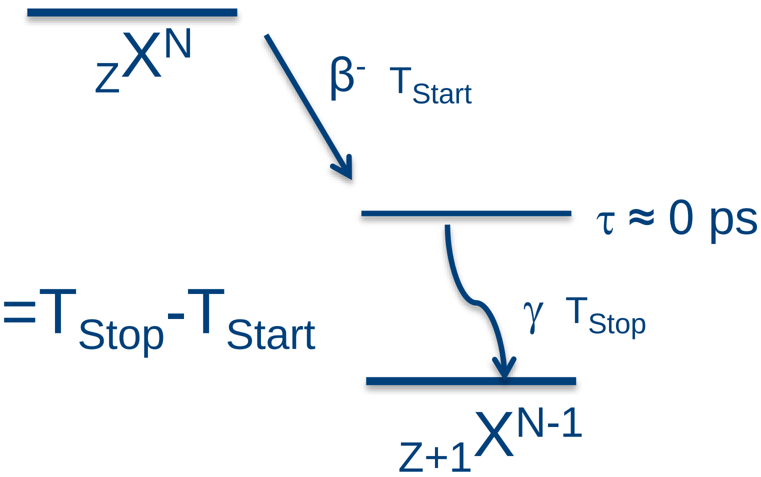
Fast-timing technique

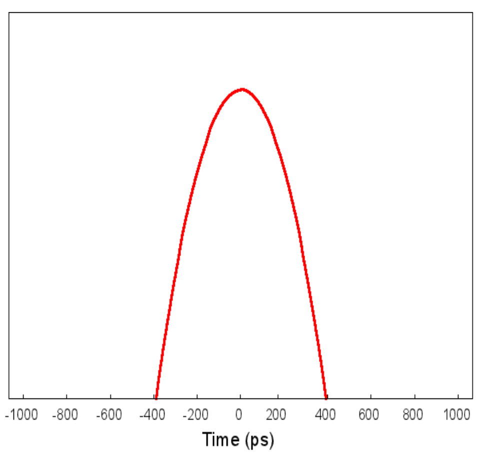


$$\Delta T = T_{Stop} - T_{Start}$$

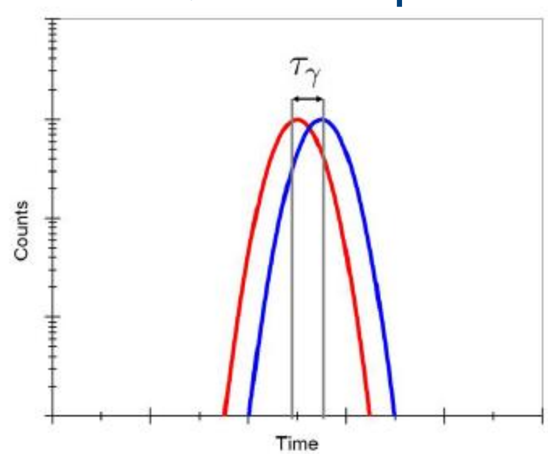
Time different between the beta plastic scintillator and the $LaBr_3$ crystal.

$\tau > 10$ ps

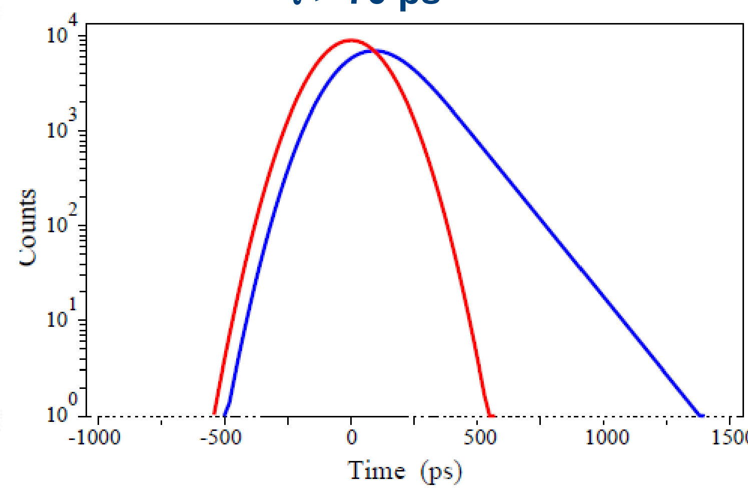
Time distribution



$\tau \sim 10 – 100$ ps



$\tau > 70$ ps



H. Mach et al., Nucl. Instr. and Meth. A 280,49-72 (1989)

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What we expect to measure

β decay:

- **$^{74-78}$Zn: To confirm and extend the level scheme.**
  Looking for possible isomeric states.
- **^{79}Zn: First decay scheme! Energy and half life of the isomeric state.**

βn branch:

- **Confirm or increase the precision on Pn values**

Lifetimes:

- **^{74,76,78}Zn: Determining the lifetimes for the 4^+ and 2^+ states.**
  Upper limit for the 6^+ state when it will be possible.
- **^{75,77,79}Zn: Measuring for first time the B(E2) and B(M1) for the most relevant states.**
  Gather more precise information on the isomeric states.

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Counting rates and shifts

Isotope*	$T_{1/2}$	Yield** [ions/μC]	Intensity IDS [pps]	Possible Cont.	β-γ_{LaBr}-γ_{LaBr} [Counts/shift]	β-γ_{LaBr}-γ_{Ge} [Counts/shift]	Shifts
^{74}Cu	1.594 s	$6.0 \cdot 10^5$	$6.0 \cdot 10^4$	Ga	$2.0 \cdot 10^2$	$1.0 \cdot 10^3$	1
^{75}Cu	1.222 s	$1.5 \cdot 10^5$	$1.5 \cdot 10^4$	Ga	$1.0 \cdot 10^3$	$5.1 \cdot 10^3$	1
^{76}Cu	0.637 s	$2.0 \cdot 10^4$	$2.0 \cdot 10^3$	Ga	$1.6 \cdot 10^2$	$7.8 \cdot 10^2$	2
^{77}Cu	468 ms	$2.0 \cdot 10^3$	$2.0 \cdot 10^2$	Ga	15	75	3
^{78}Cu	335 ms	$2.0 \cdot 10^2$	20	Ga & Rb	4.6	23	7
^{79}Cu	188 ms	20	2	Ga & Rb	7.1	35	9
^{80}Cu	114 ms	~ 1	~ 0.1	Ga & Rb	?	?	1

24 shifts

Counts estimated for the γ cascade:
- ^{74,76,78}Zn: $4^+ \rightarrow 2^+$ and $2^+ \rightarrow 0^+$
- ^{75}Zn: $7/2^- \rightarrow 5/2^-$ and $5/2^- \rightarrow 7/2^+$
- ^{77}Zn: $5/2^+ \rightarrow 3/2^+$ and $3/2^+ \rightarrow 1/2^-$
- ^{79}Zn: Only β–γ coincidence for the $5/2^+ \rightarrow 9/2^+$

Contamination:
- Never > 1:200
- Neutron converter!

Calibration shits:
- ^{138}Cs: 1 shift
- ^{88}Rb: 1 shift
- ^{24}Na: 0.1 shift

Total: 26 shifts

* RILIS for the Ionization

** Yields proton on target extracted from ISOLDE website. For a UCx target.

A. Illana[1], B. Olaizola[2], L.M. Fraile[3], M. Huyse[1], P. Van Duppen[1], P. Garrett[2], A.N. Andreyev[4], J. Benito[3], T. Berry[5], M. Carmona[3], H. De Witte[1], G. Fernandez-Martinez[6], H.O.U. Fynbo[7], A. Gottardo[8], P.T. Greenlees[9], L.J. Harkness-Brennan[10], S. Ilieva[6], D.S. Judson[10], J. Konki[9], T.Kröll[6], J. Kurcewicz[11], I. Lazarus[12], R. Lica[11;13], M. Lund[7], M. Madurga[11], N. Marginean[13], R. Marginean[13], I. Marroquín[14], C. Mihai[13], D. Mücher[2], E. Nacher[14], A. Negret[13], C.R. Nita[13], R. Orlandi[15], R.D. Page[10], S. Pascu[13], A. Perea[14], Zs. Podolyak[5], V. Pucknell[12], E. Rapisarda[16], P. Rahkila[9], F. Rotaru[13], C. Sotty[13], O. Tengblad[14], V. Vedia[3], R. Wadsworth[4], J.J. Valiente-Dobon[17], N. Warr[18]

(IDS Collaboration)

[1]KU Leuven, Instituut voor Kern- en Stralingsfysica, Leuven, Belgium. [2]Department of Physics, University of Guelph, Guelph ON, Canada. [3]Grupo de Física Nuclear, Facultad de CC. Físicas, Universidad Complutense, Madrid, Spain. [4]University of York, Dept. Phys., York, United Kingdom. [5]University of Surrey, Surrey, United Kingdom. [6]Technische Universität Darmstadt, Darmstadt, Germany. [7]Department of Physics and Astronomy, Aarhus University, Aarhus C, Denmark. [8]Institut de Physique Nucléaire, CNRS-IN2P3, Université Paris-Sud, Orsay, France. [8]University of Jyvaskyla, Department of Physics, University of Jyväskylä, Jyväskylä, Finland. [10]Department of Physics, Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom. [11]ISOLDE, CERN, Switzerland. [12]STFC Daresbury, Daresbury, United Kingdom. [13]"Horia Hulubei" National Institute of Physics and Nuclear Engineering, Bucharest, Romania . [14]Instituto de Estructura de la Materia, CSIC, Madrid, Spain. [15]Advanced Science Research Center, Japan Atomic Energy Agency, Tokai, Japan. [16]Paul Scherrer Institut, Villigen, Switzerland. [17]INFN, Laboratori Nazionali di Legnaro, Legnaro, Italy. [18]Institut für Kernphysik, Universitätt zu Köln, Köln, Germany

THANKS FOR YOUR ATTENTION

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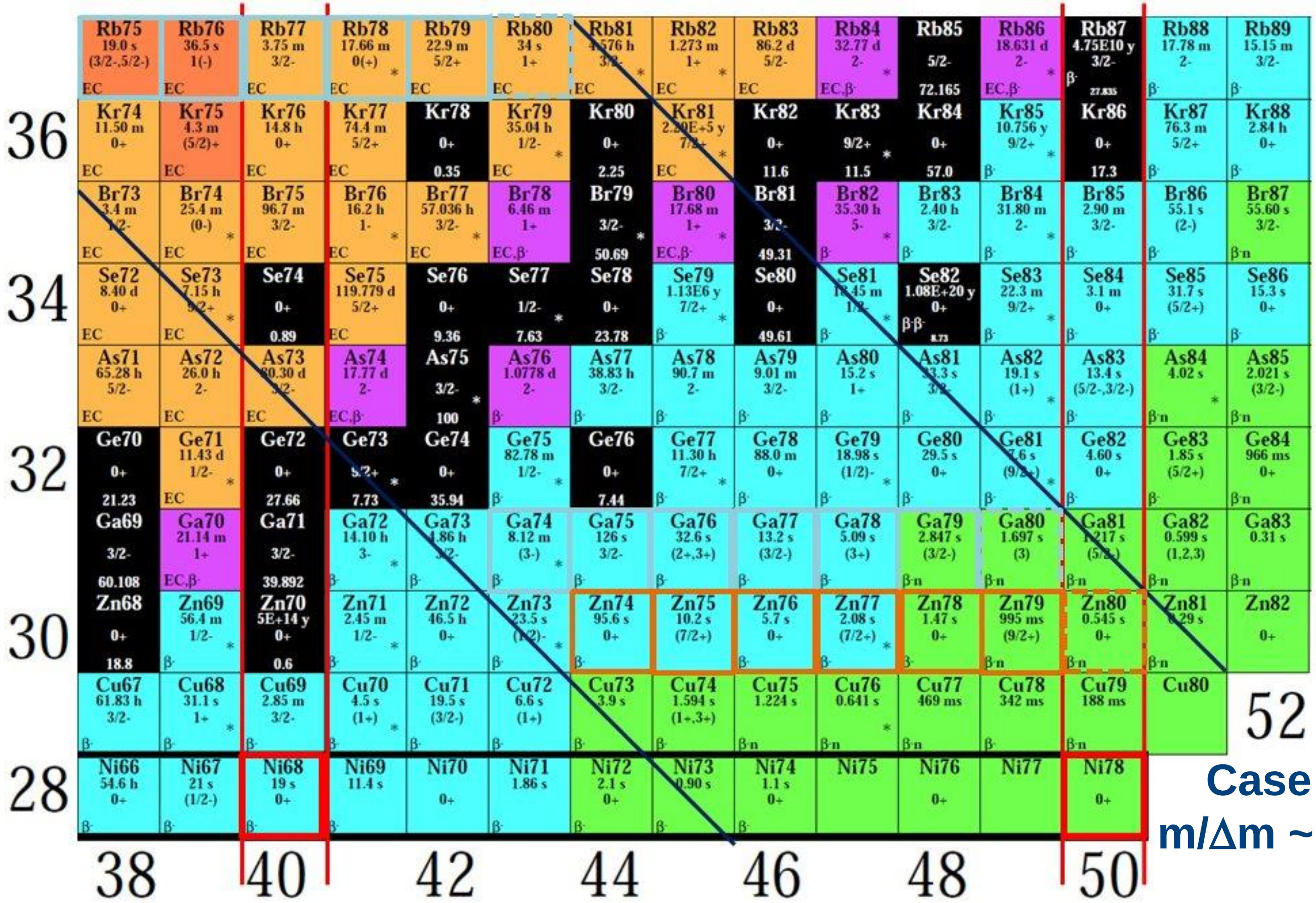
What contamination will we expect?



Case A = 78:
m/Δm ~ 3236 (73)

Neutron converter +HRS will reduce all the Rb contaminant
Ga contaminant: A = 75 ~ 1:5 and A = 77 < 1:50.

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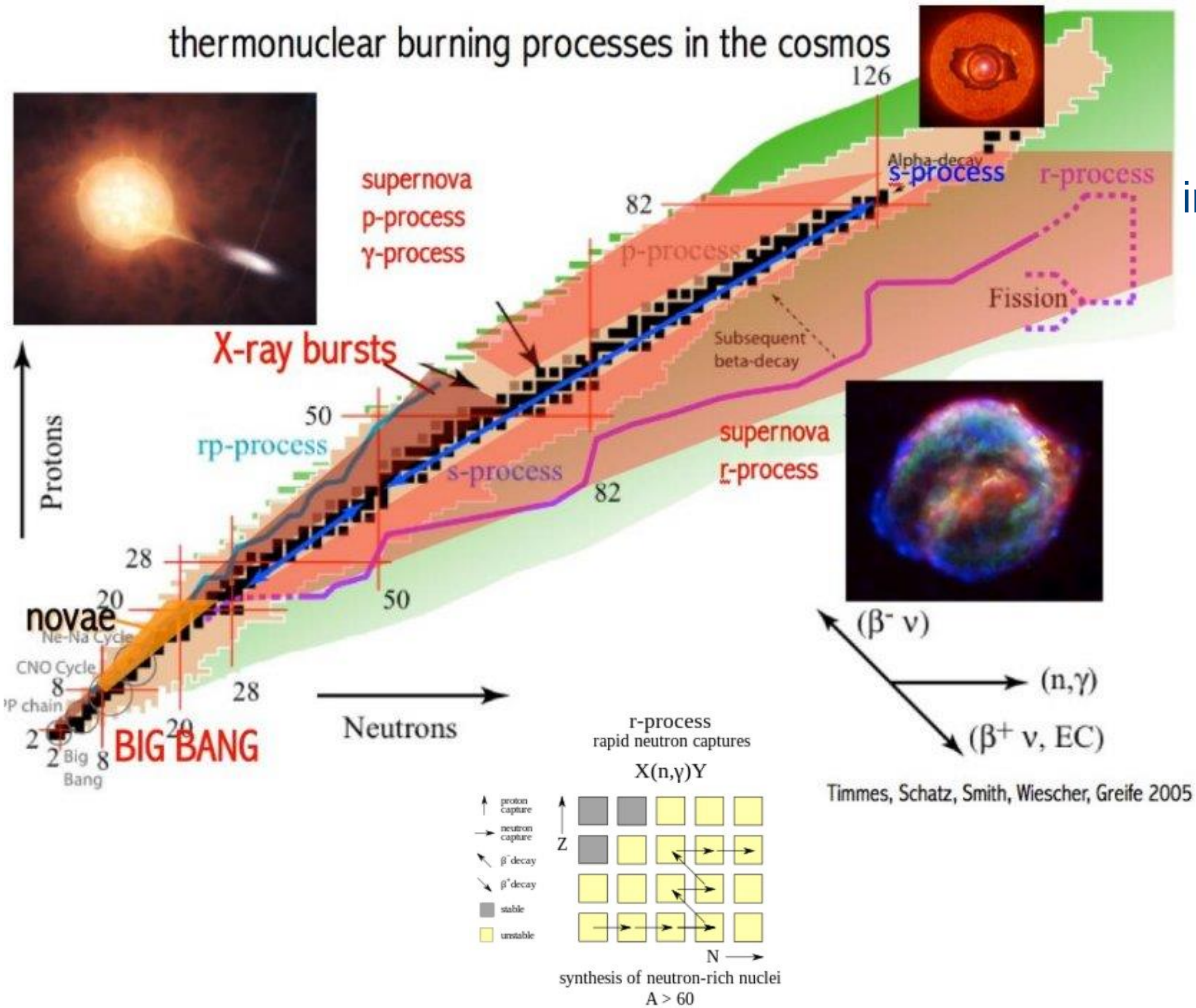
Motivation



Our study has a big impact for understanding **the r-process**.

Why?

β decay, half-lives and the β-delayed neutron emission around the **waiting points** are **essential** inputs for the theoretical model predictions.

R.A. Surman et al., capture Gamma-ray spectroscopy and related topics, 41, 304-313(2013)

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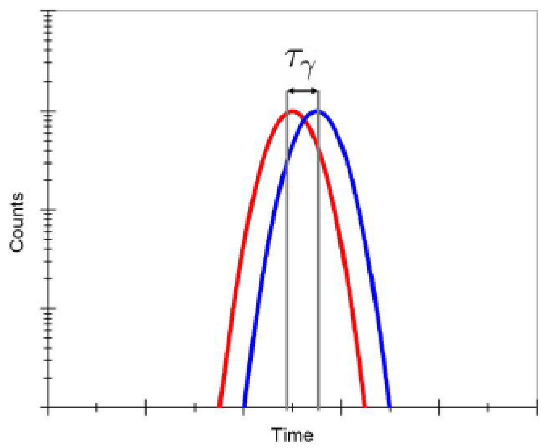
Centroid shift technique

- Centroid shift is used for $T_{1/2} < 2/3\text{FWHM}$
- The time difference between a β event and a (semi-)prompt γ presents a Gaussian distribution
- Shift between the centroid of the prompt reference and our time distribution gives τ of the level
- Has a lower limit of 5-10 ps



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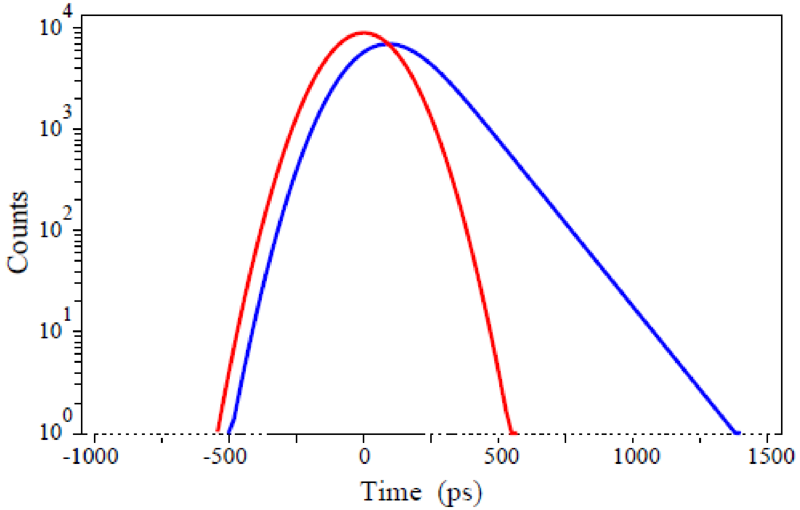
Convolution technique

- Prompt part may be approximated to a Gaussian shape, down to 3 orders of magnitude
- Slope method may be used for $T_{1/2} > 2/3\mathrm{FWHM}$
- Fit of the timing distribution to a prompt response plus a exponential decay
- $F(t_j) = \gamma \int_A^{+\infty} e^{-\delta(t_j - t)} e^{-\lambda(t-A)} dt$



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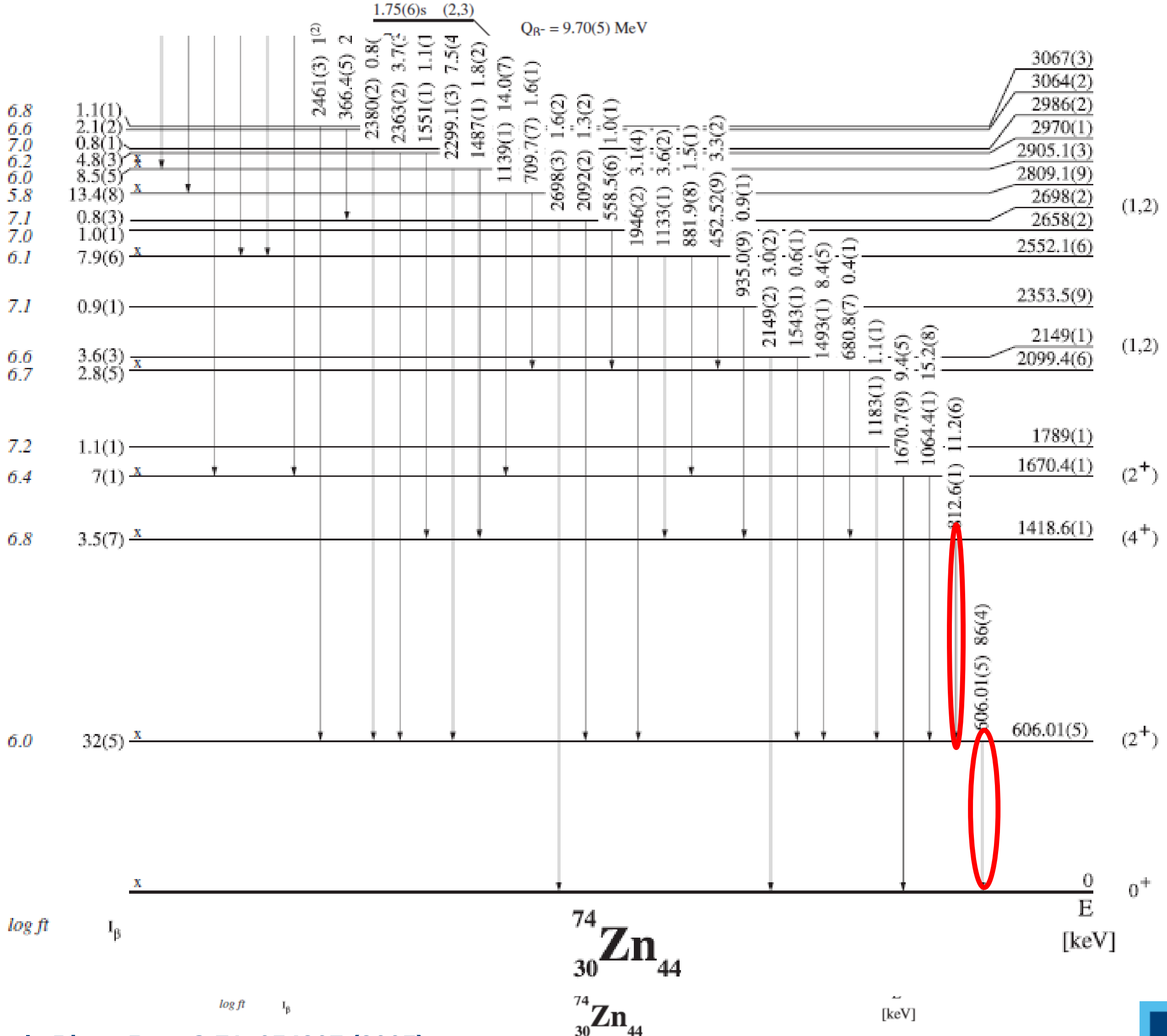
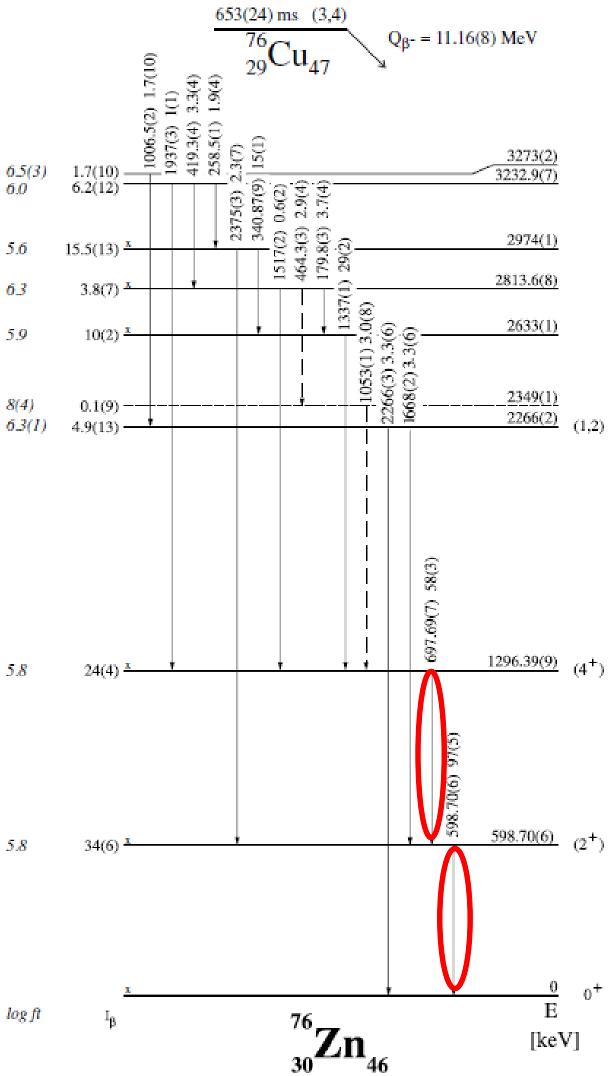
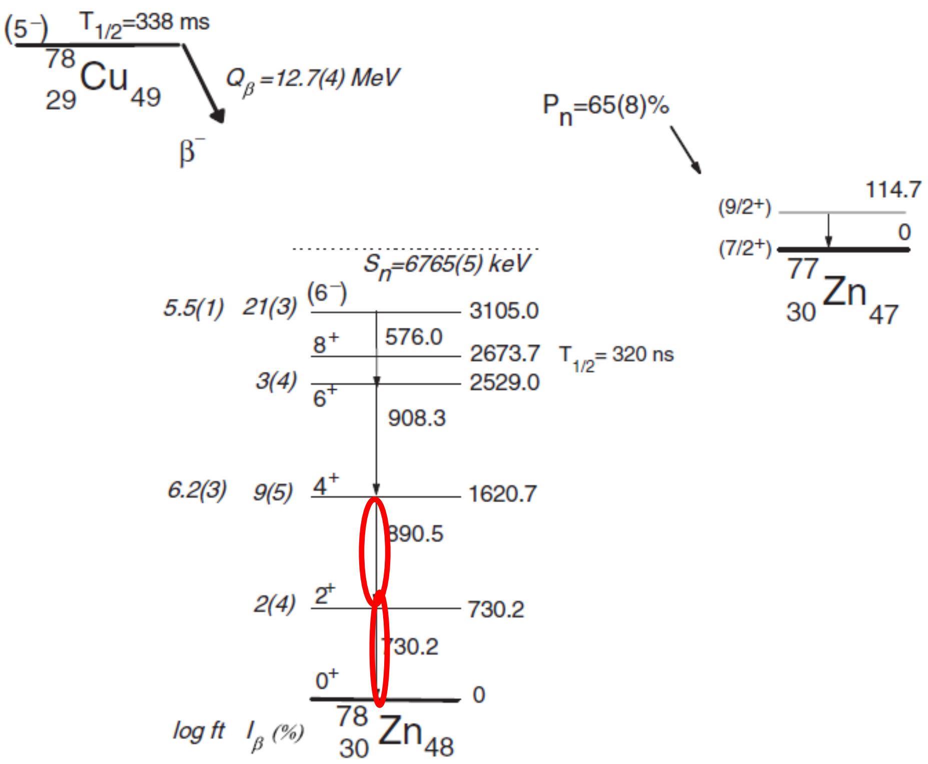
Known about: ^{74}Zn



J. Van Roosbroeck et al., Phys. Rev. C 71, 054307 (2005)

Known about: ^{76,78}Zn





J. Van Roosbroeck et al., Phys. Rev. C 71, 054307 (2005)

A. Korgul et al., Phys. Rev. C 86, 024307(2012)

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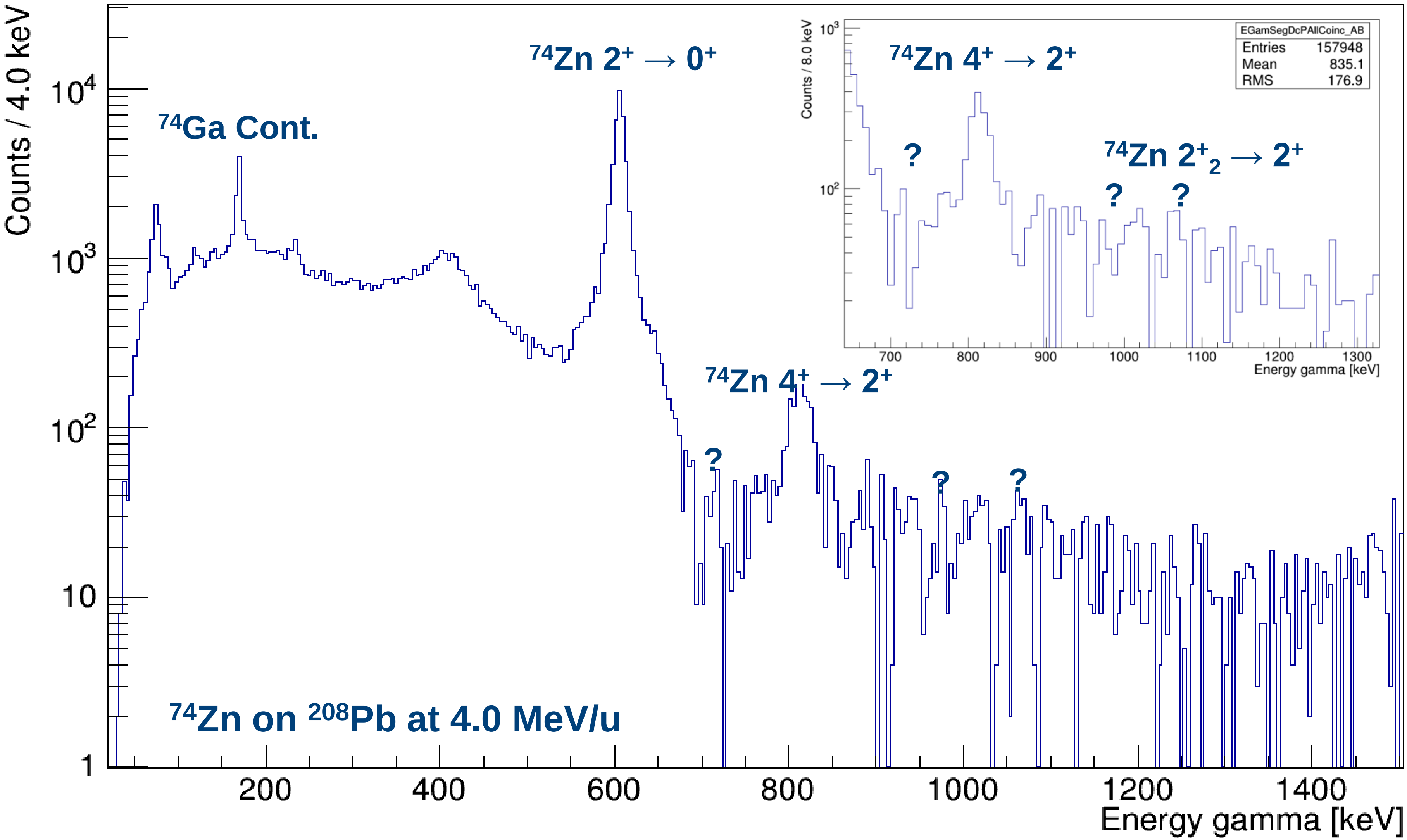

Counts / 4.0 keV
10^4
10^3
10^2
10
1
200
400
600
800
1000
1200
1400
Energy gamma [keV]
^{74}Ga Cont.
^{74}Zn $2^+ \rightarrow 0^+$
^{74}Zn $4^+ \rightarrow 2^+$
?
?
?
^{74}Zn on ^{208}Pb at 4.0 MeV/u
Counts / 8.0 keV
10^3
10^2
700
800
900
1000
1100
1200
1300
Energy gamma [keV]
EGamSegDcPAllCoinc_AB
Entries 157948
Mean 835.1
RMS 176.9
^{74}Zn $4^+ \rightarrow 2^+$
?
^{74}Zn $2^+_2 \rightarrow 2^+$
?
?

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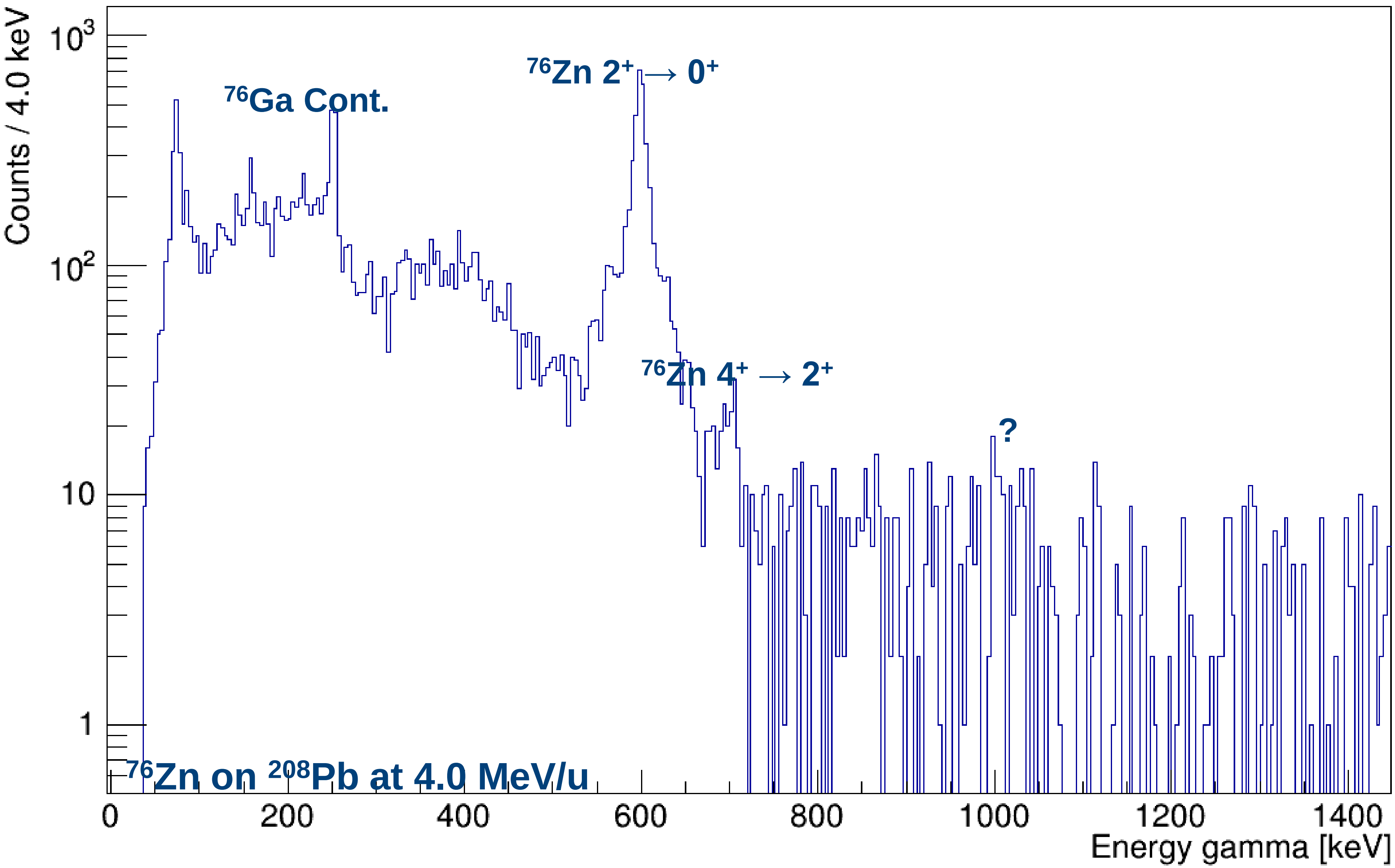

Counts / 4.0 keV
10^3
10^2
10
1
^{76}Ga Cont.
^{76}Zn $2^+ \rightarrow 0^+$
^{76}Zn $4^+ \rightarrow 2^+$
?
^{76}Zn on ^{208}Pb at 4.0 MeV/u
0
200
400
600
800
1000
1200
1400
Energy gamma [keV]

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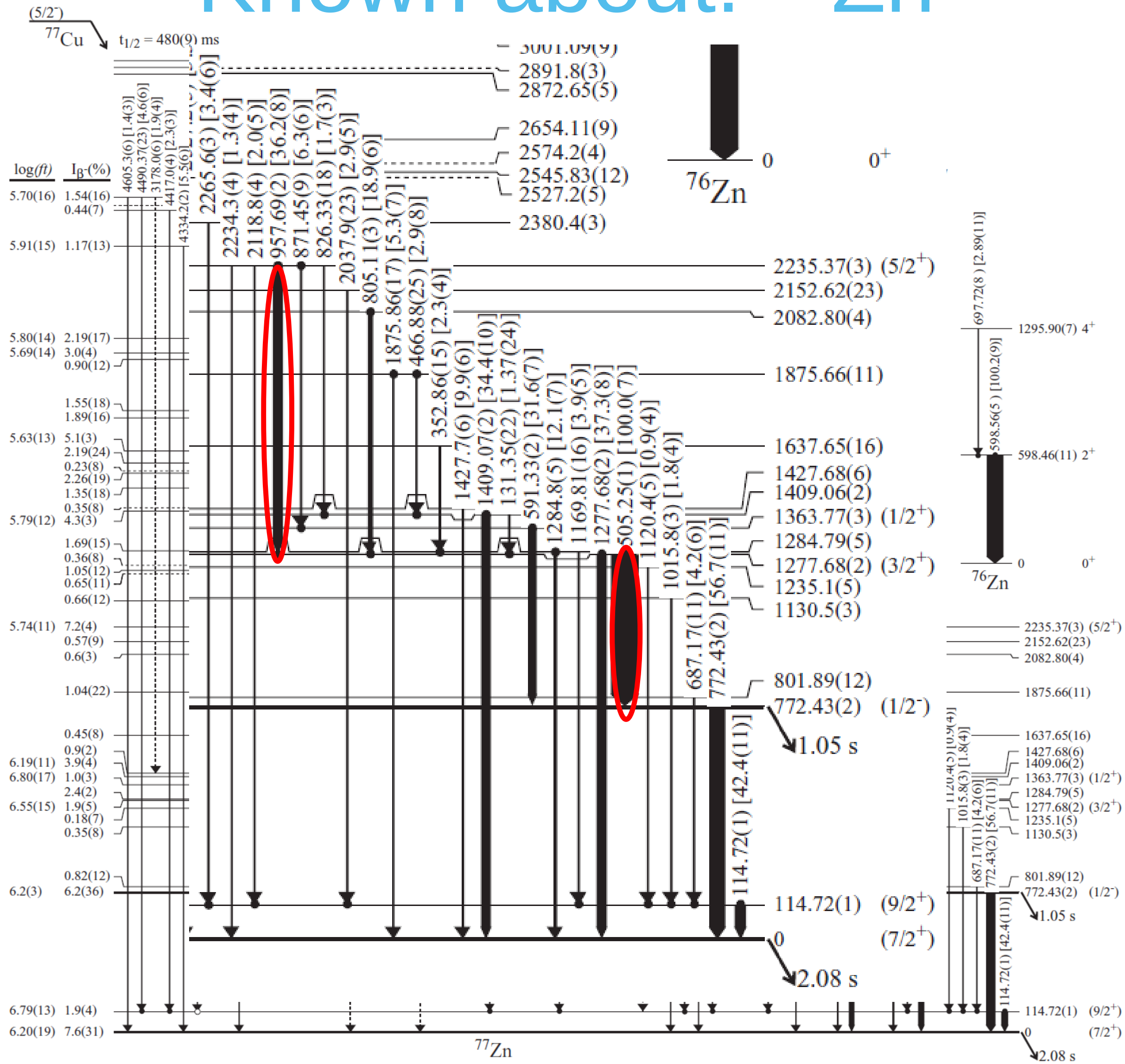
Known about: ^{77}Zn



S.V. Ilyushkin et al., Phys. Rev. C 80, 054304 (2009)

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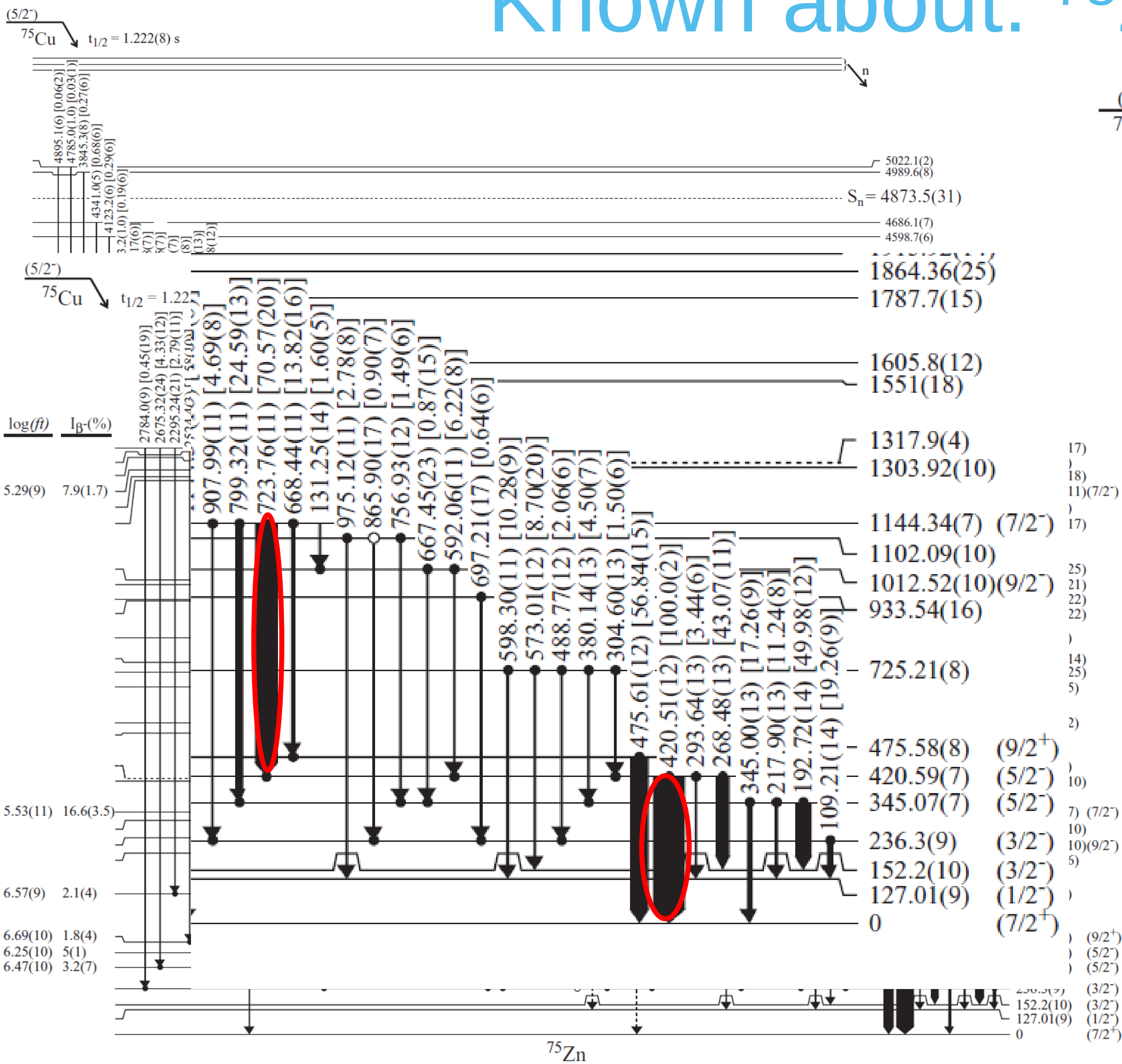
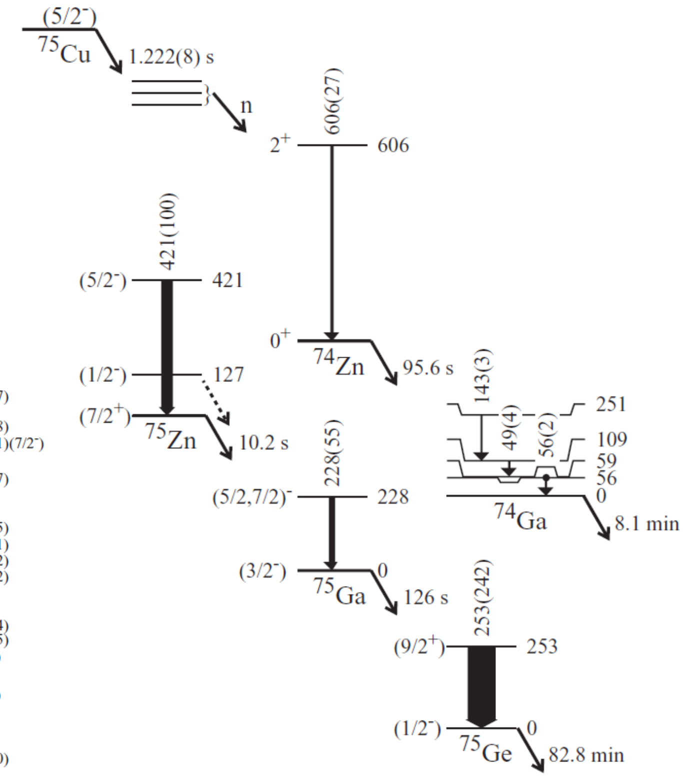
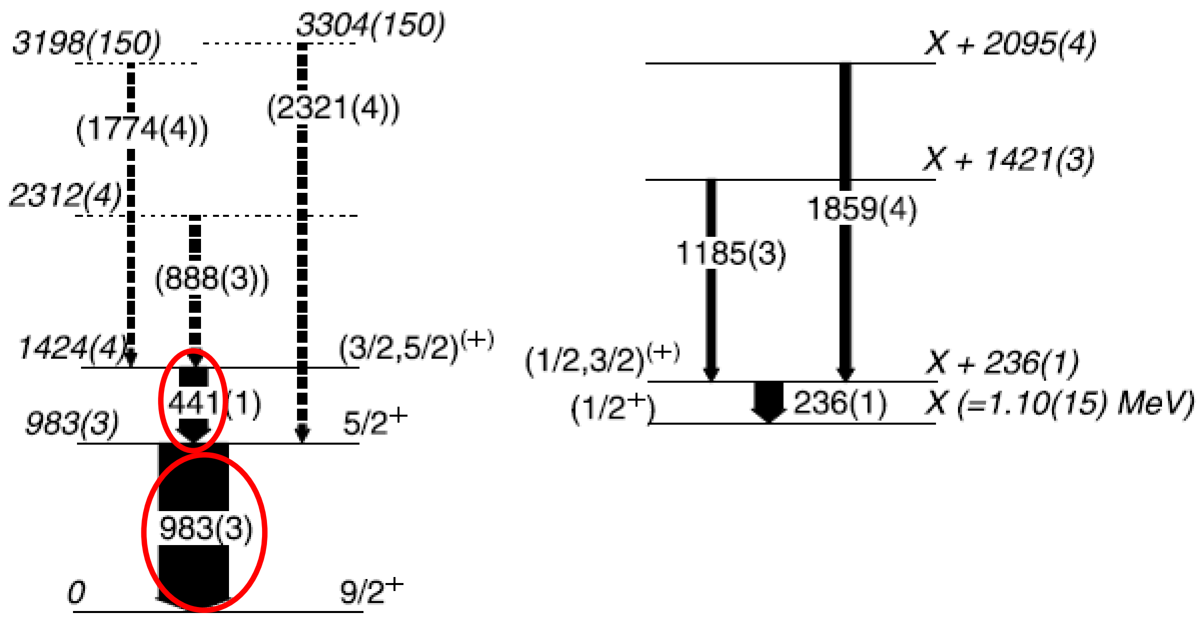
Known about: ^{75}Zn



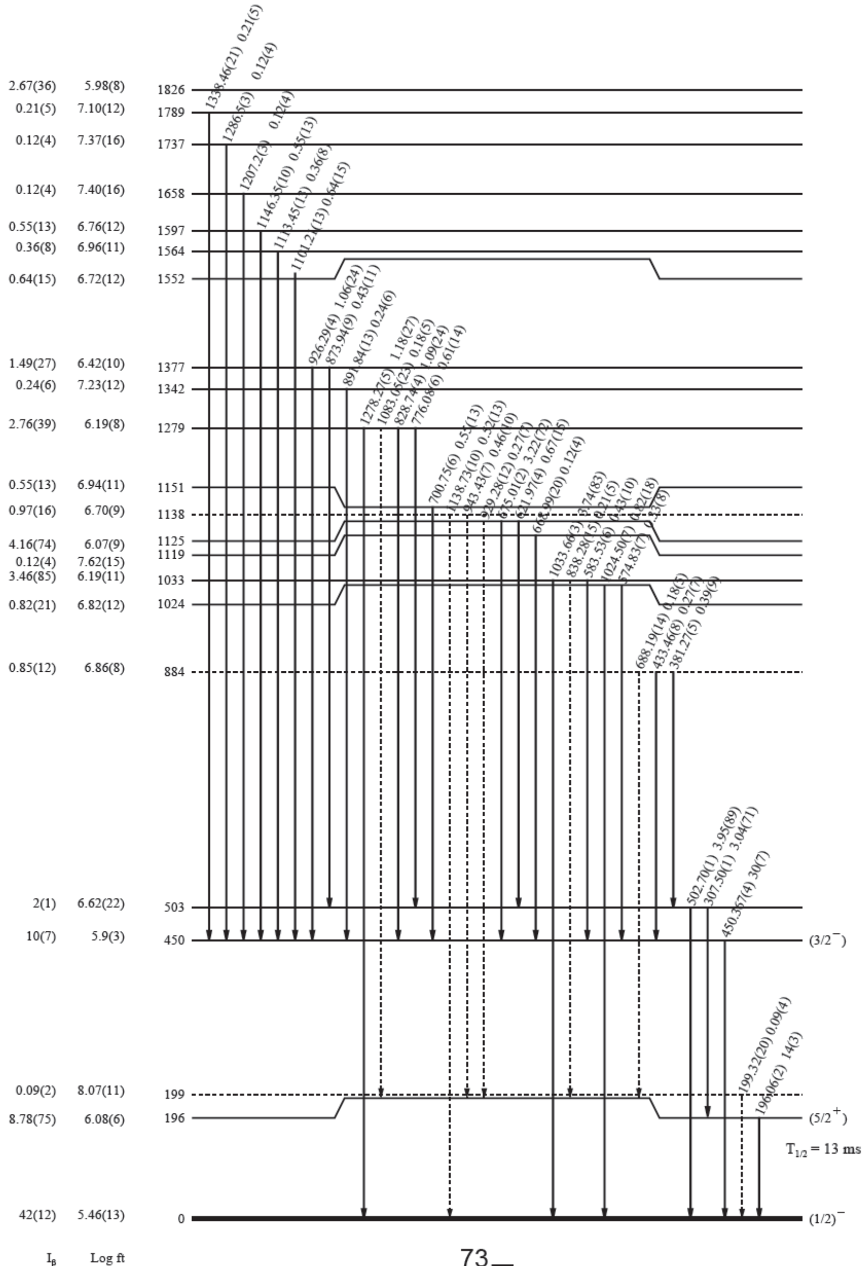


S.V. Ilyushkin et al., Phys. Rev. C 83, 014322 (2011)

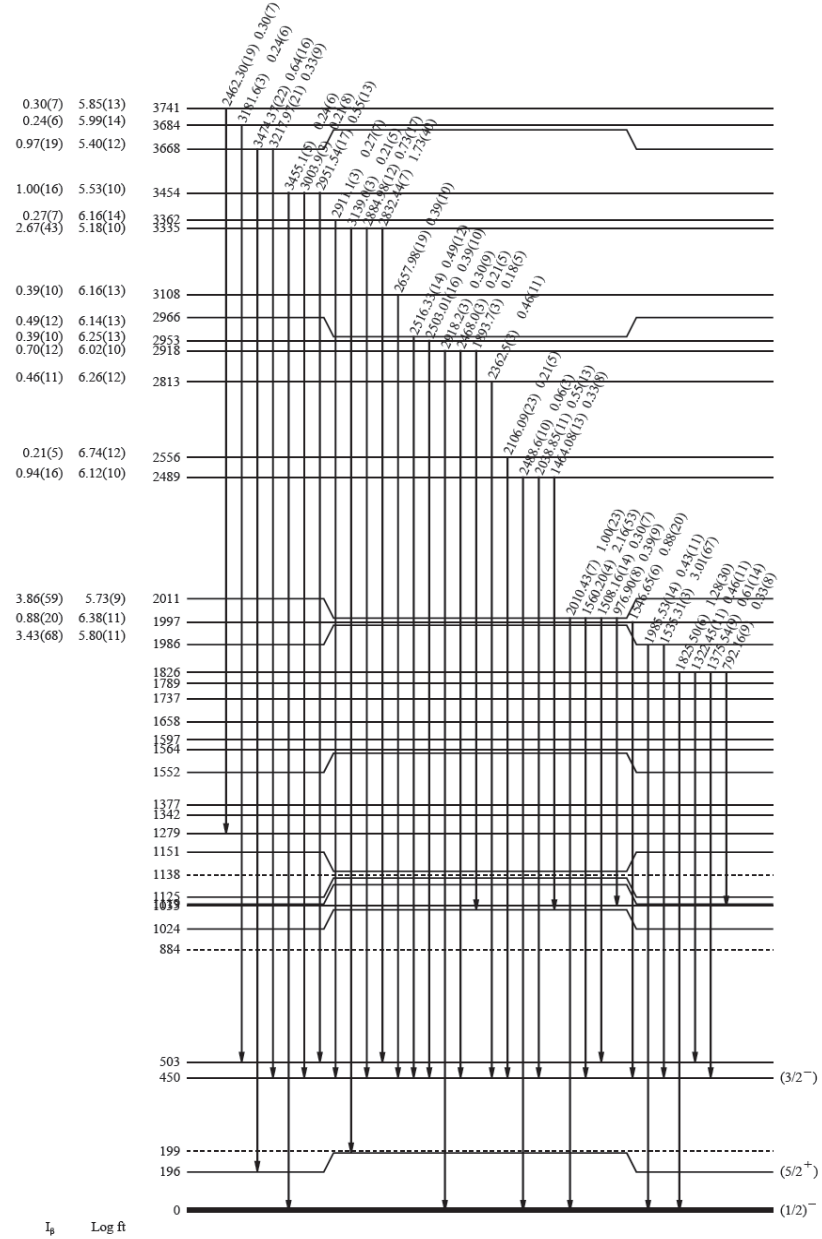
Known about: ^{79}Zn



R. Orlandi et al., Phys. Lett. B 740, 298-302 (2015)



$^{73}_{30}Zn$



$^{73}_{30}Zn$