Fast timing study of single-particle and collective aspects in nuclei near ^{78}Ni

Status Report for experiments IS441 and IS474

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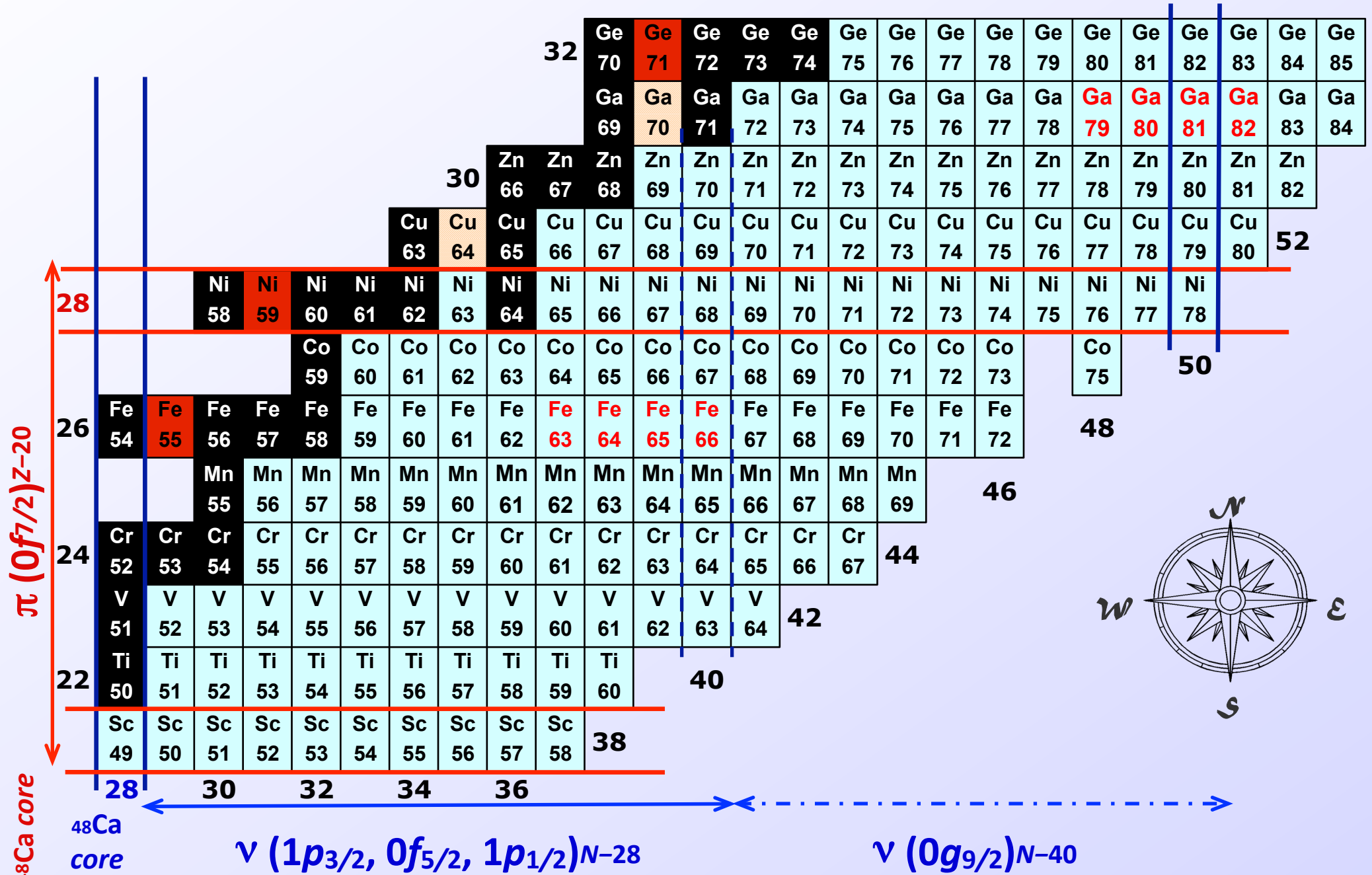
Nuclear chart ^{68}Ni – ^{78}Ni



Fast-timing studies of nuclei below ^{68}Ni populated in the beta-decay of Mn isotopes

Spokespersons: L.M. Fraile, H. Mach

→ Below Z=28 shell closure, $\pi\,(f_{7/2})^{Z-20}$

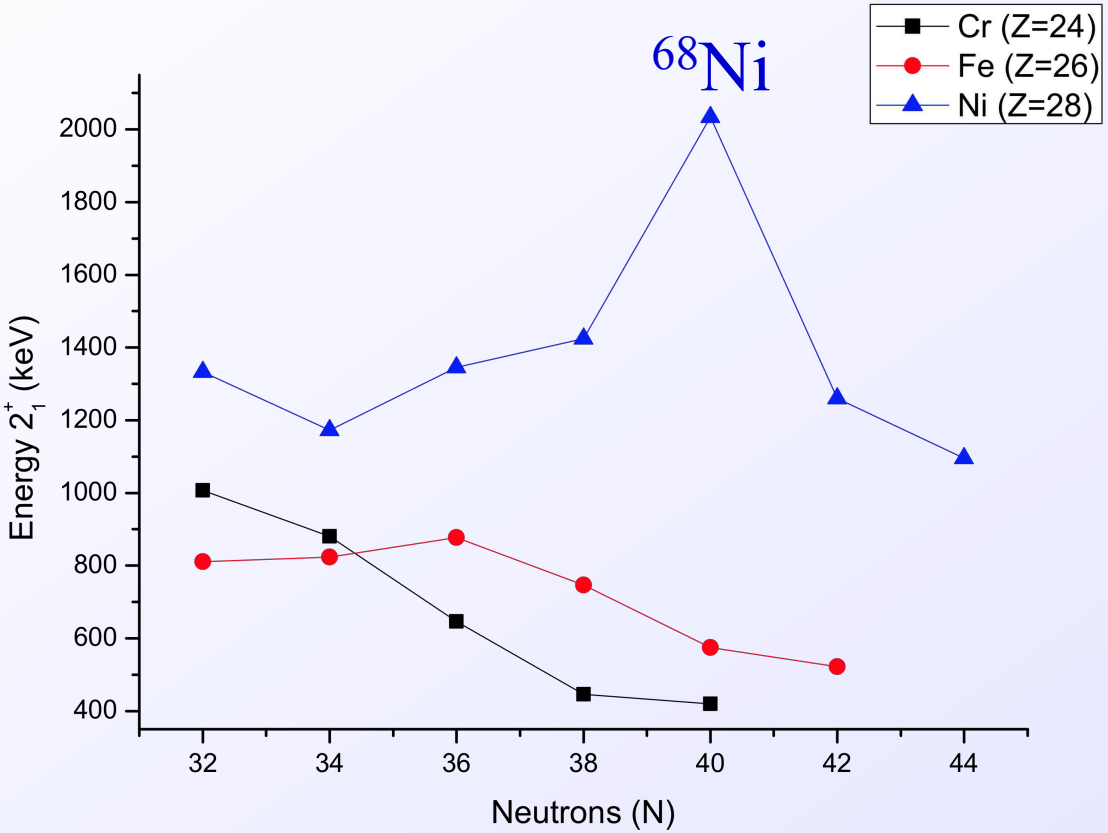
→ Neutrons filling $\nu(p_{3/2}, f_{5/2}, p_{1/2})$ and $\nu(g_{9/2})$ (and…)

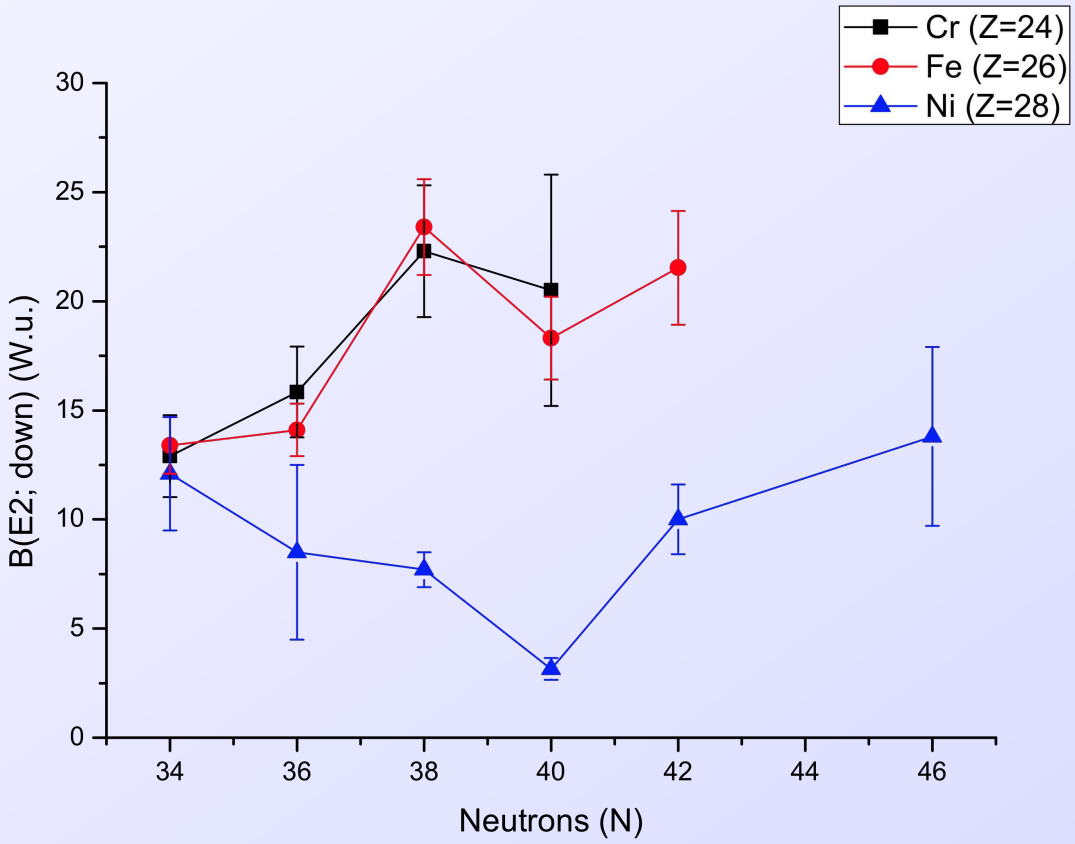
→ N=40 subshell?

→ Evolution of collectivity: deformation

→ Isomers – role of the $g_{9/2}$ orbital

2^+ and B(E2) systematics





- ^{68}Ni: B(E2;$0^+ \rightarrow 2^+$) = 265 e^2fm^4 = 3.2 W.u.
- ^{64}Cr: 420 keV, B(E2;$0^+ \rightarrow 2^+$) = 21(5) W.u.
- Shell-model calculations using only the *pfg* neutron valence space fail to correctly describe the collectivity at N = 40

  specially 573 keV 2^+ state in ^{66}Fe

  require also an inclusion of the neutron $1d_{5/2}$ orbital **[Caurier et al., EPJA15 2002]**

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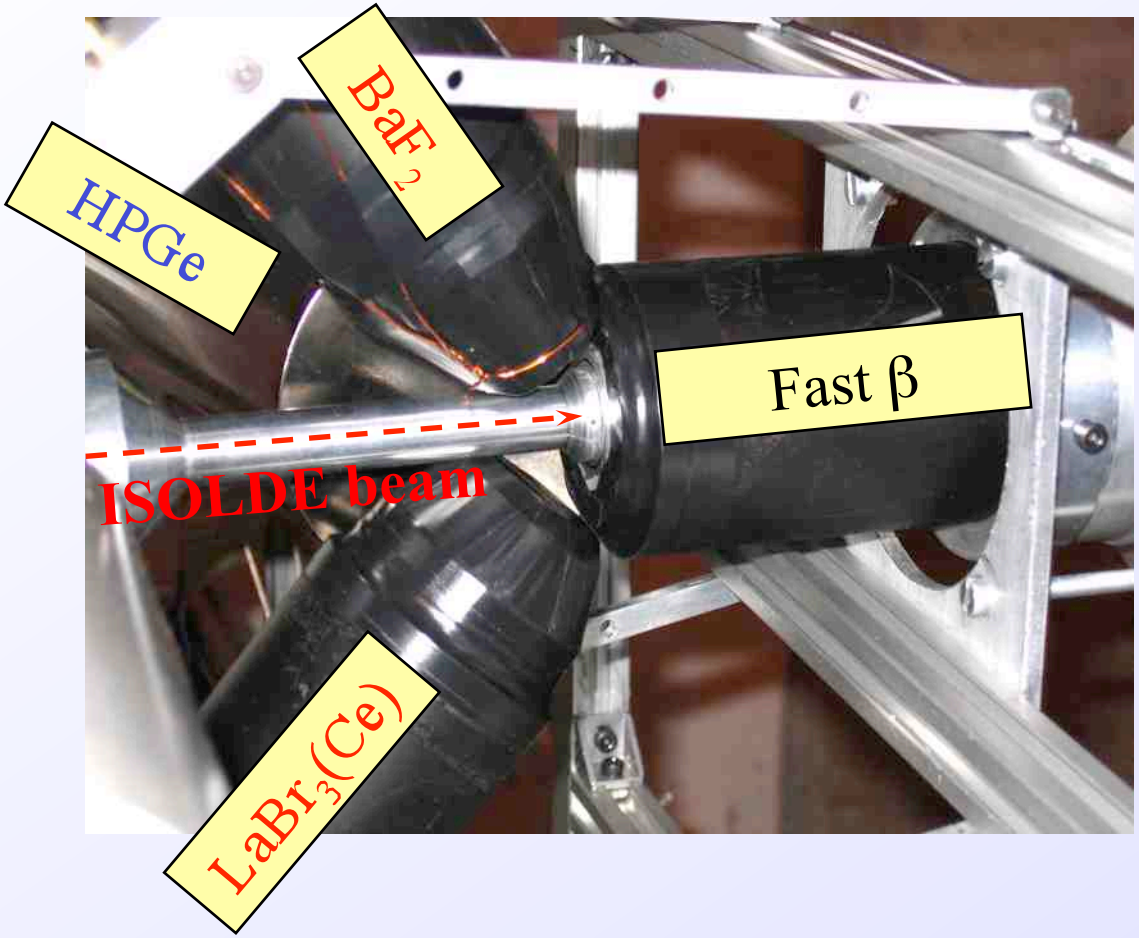
TRANSITION RATES

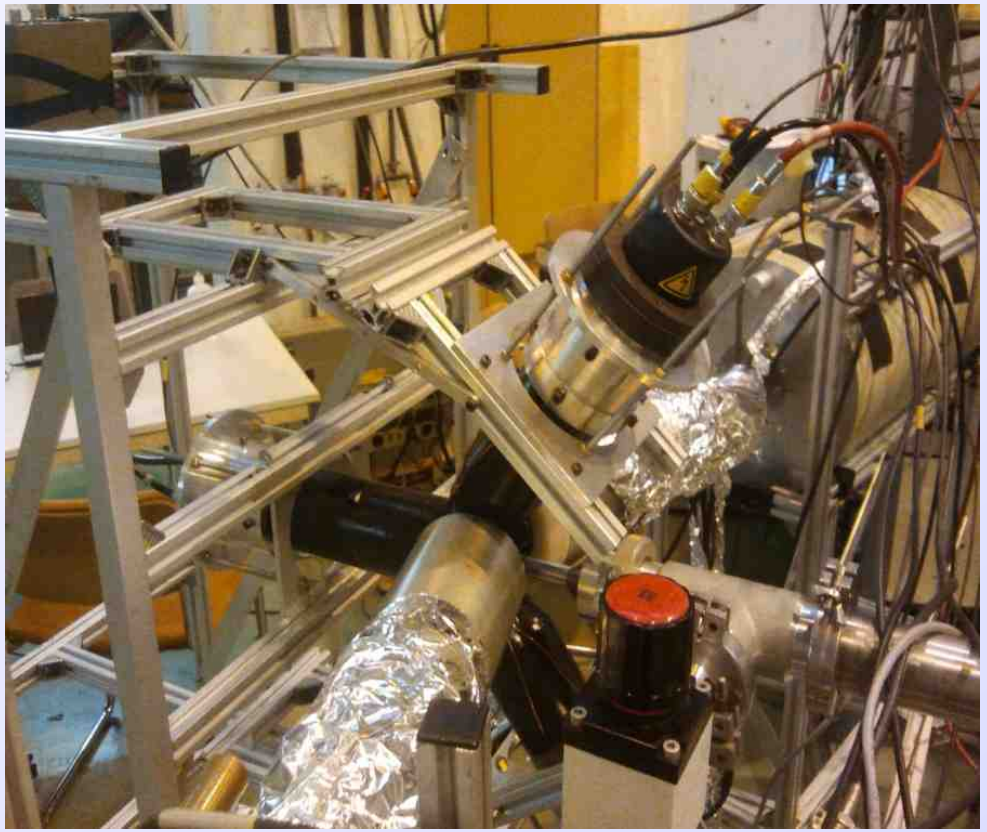
→ Stringent tests of theoretical models

→ Probe the collective and single-particle nature of states

→ Systematics

FAST-TIMING $\beta\gamma\gamma(t)$ setup



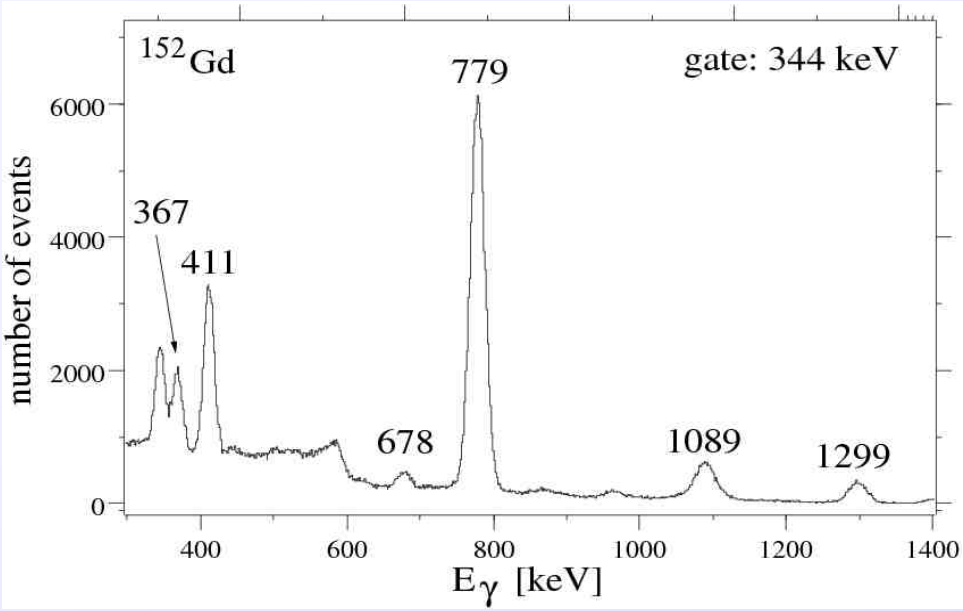


HPGe:
High energy resolution
Poor time response

TIMING
$LaBr_3(Ce)$: Fast response γ-detectors / poor energy resolution
Plastic β scintillator: Fast response / efficient start detector

Timing with $LaBr_3(Ce)$ scintillators

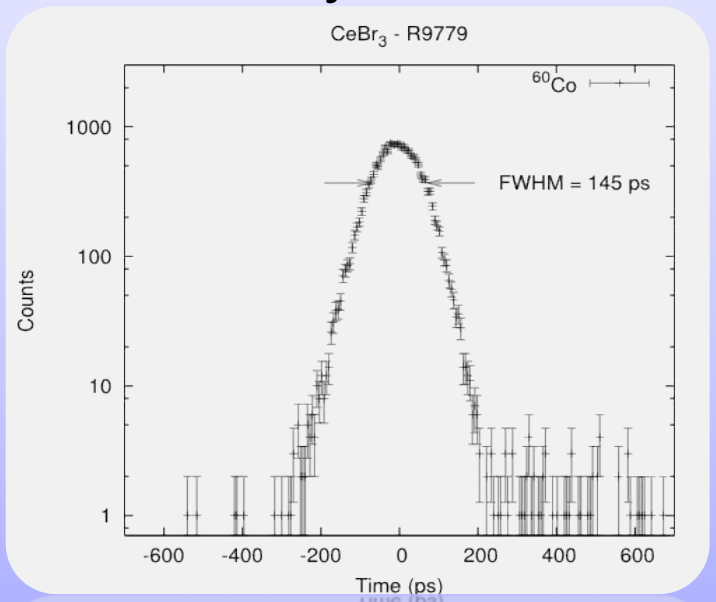
- ✓ β–γ combinations
  - → FEP walk calibration
  - → Prompt (Compton) walk calibration
  - → Better peak to Compton
- ✓ γ–γ timing
  - → E resolution: selection of branches



Alternatives under study

$CeBr_3$

FWHM
119 ± 2 ps
at ^{60}Co



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DAQ systems

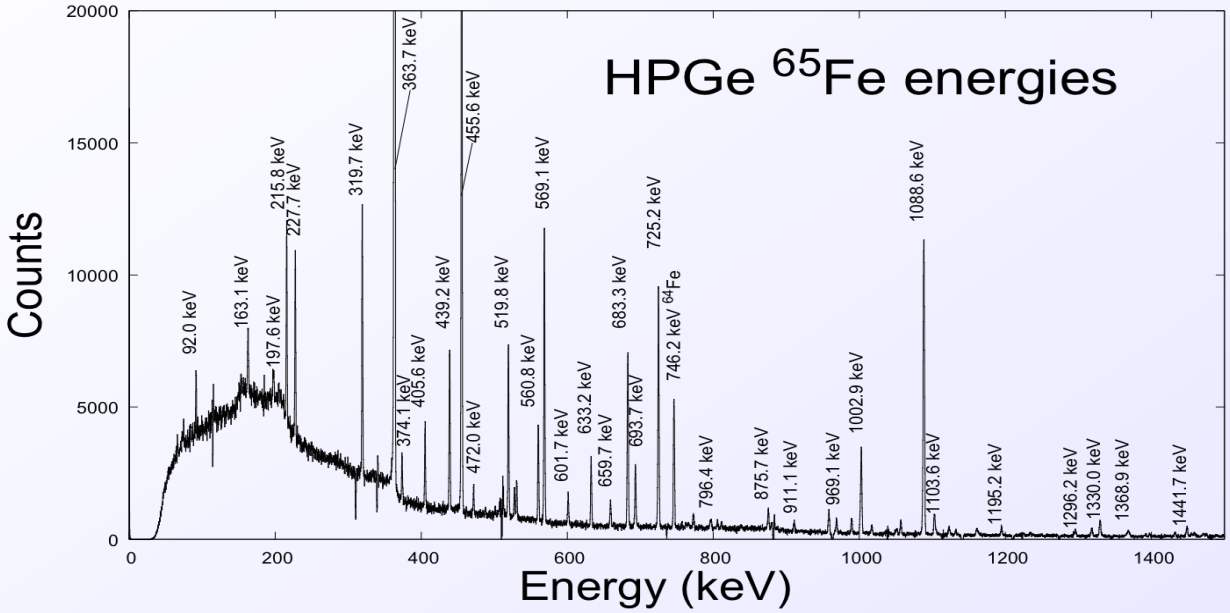
IS474 Mn: analog MP, digital XIA Pixie-4 Rev. C
IS441 Zn: digital XIA Pixie-4 Rev. C - 75MHz

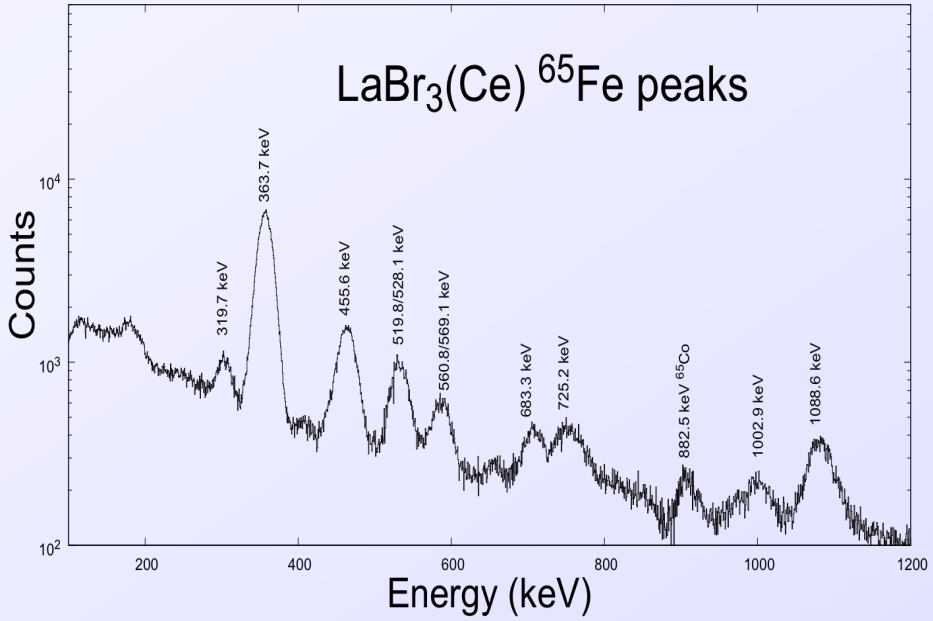
Uses **TACs** for time differences and preprocessing of energies

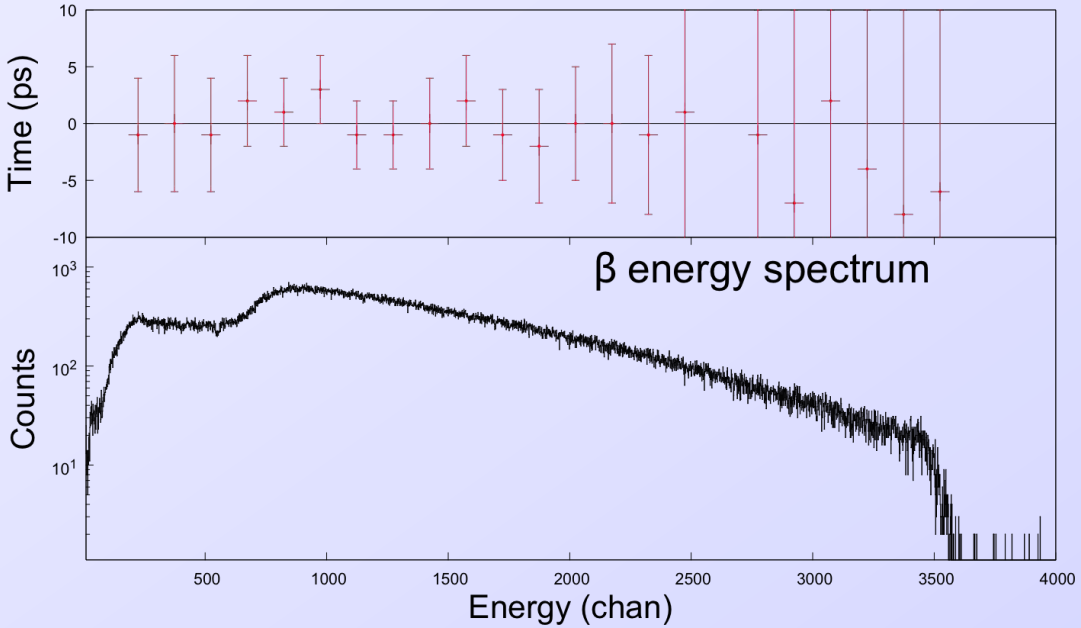
Pixie XIA:

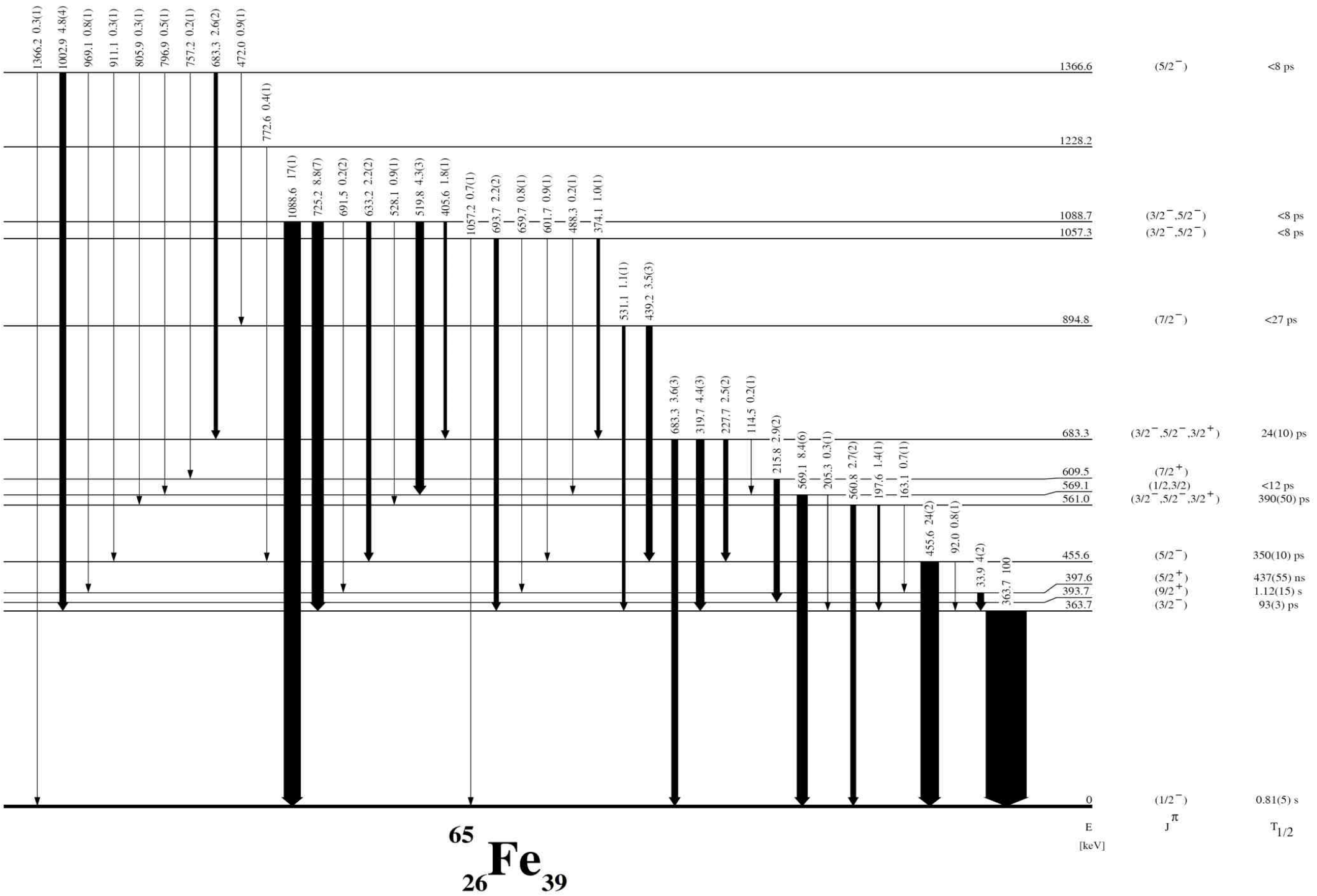
- γ-ray singles
- β-gated γ-ray singles β-Ge
- βγ coincidences β-$LaBr_3$ (timing)
- γγ coincidences Ge-Ge
- γγ coincidences $LaBr_3$-$LaBr_3$ (timing)
- βγγ coincidences β-Ge-Ge
- βγγ coincidences β-Ge-$LaBr_3$ (timing)

IS474: example for ^{65}Fe

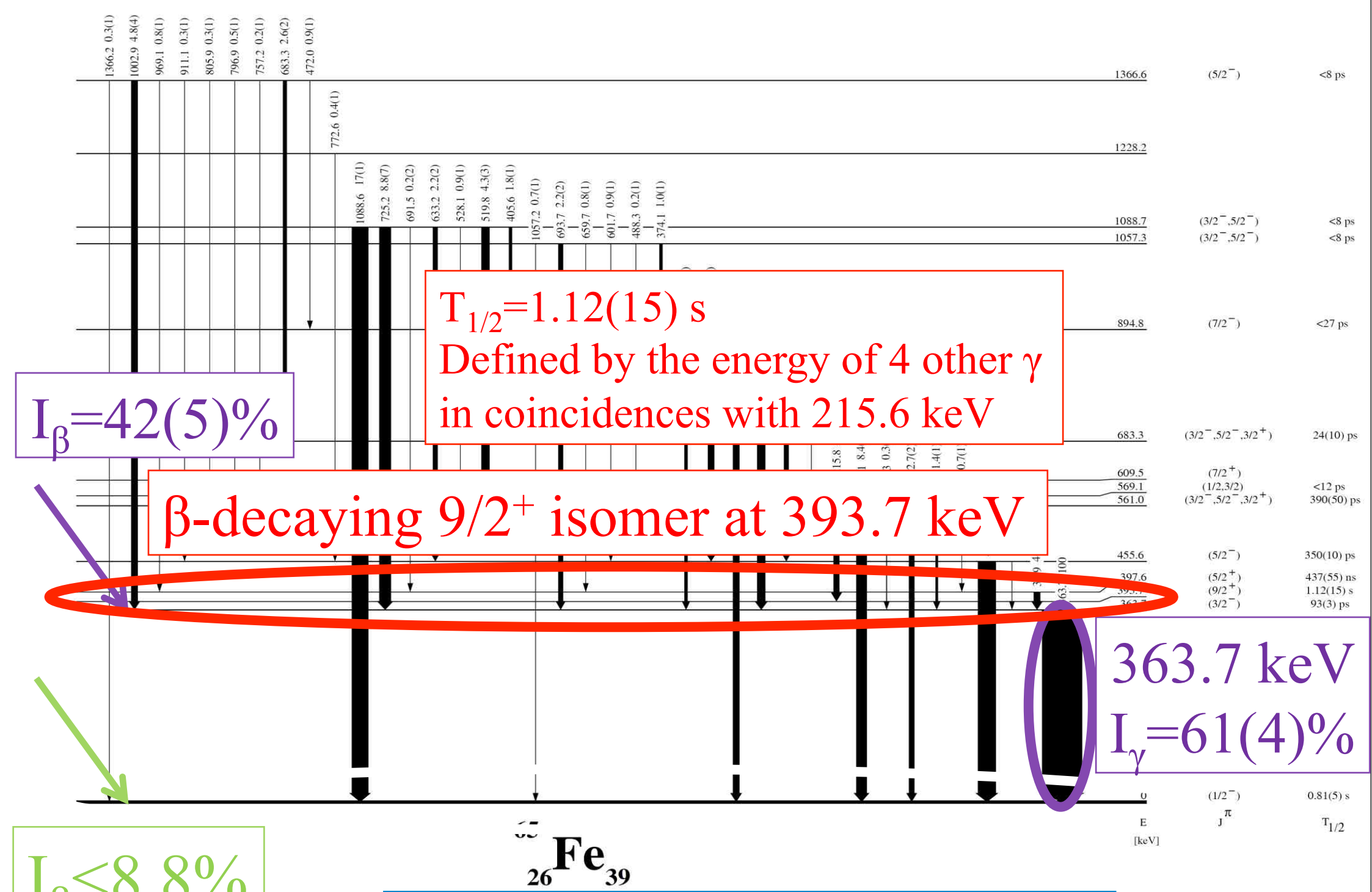








B. Olaizola *et al.* PRC88, 044306 (2013)



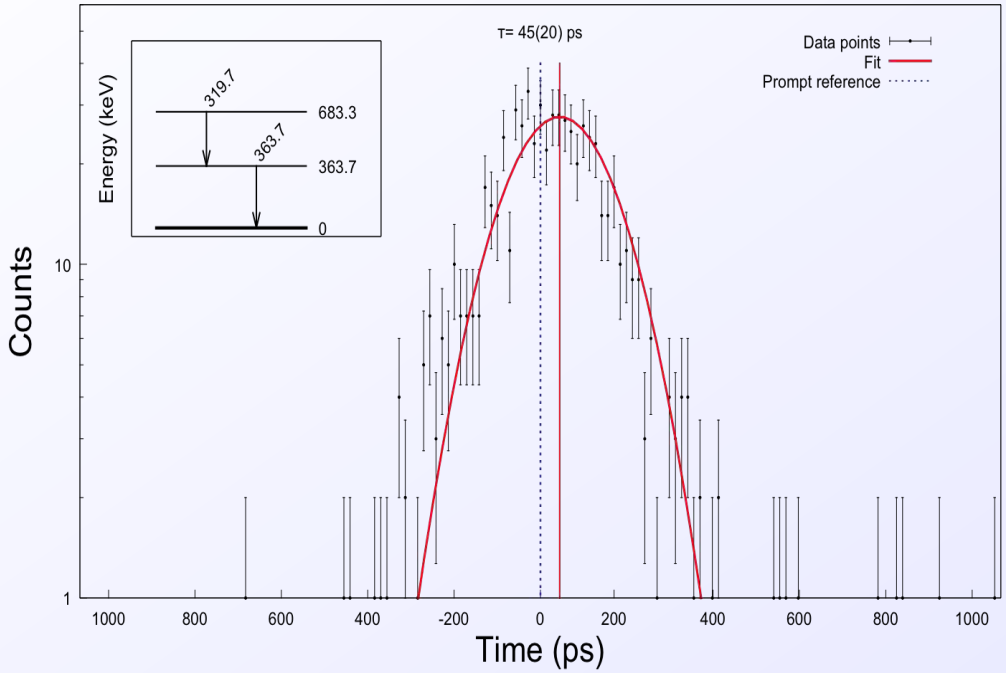
B. Olaizola *et al.* PRC88, 044306 (2013)

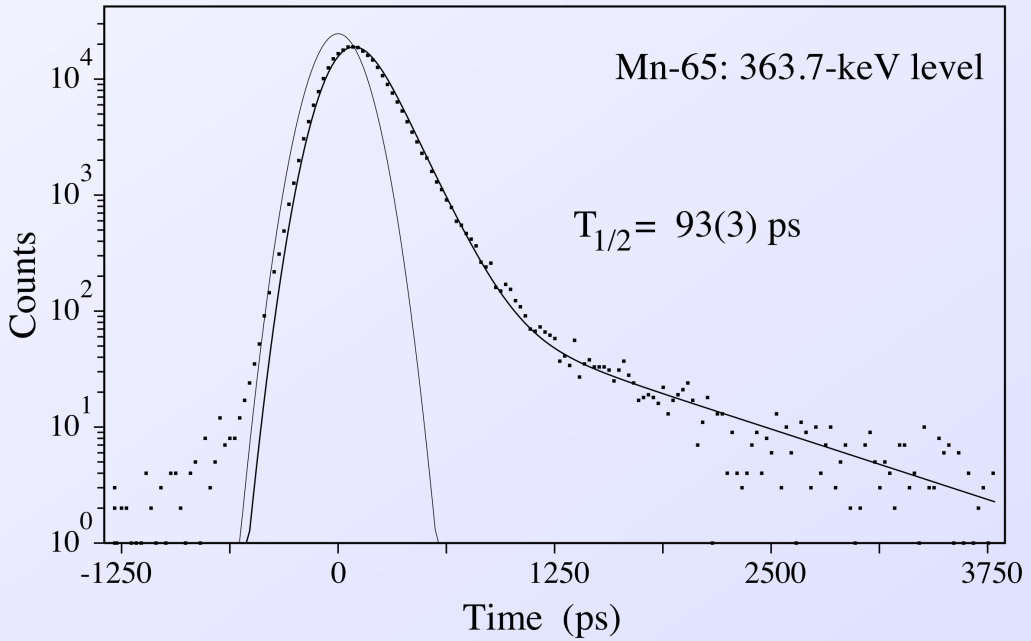
^{65}Fe from the beta decay of ^{65}Mn

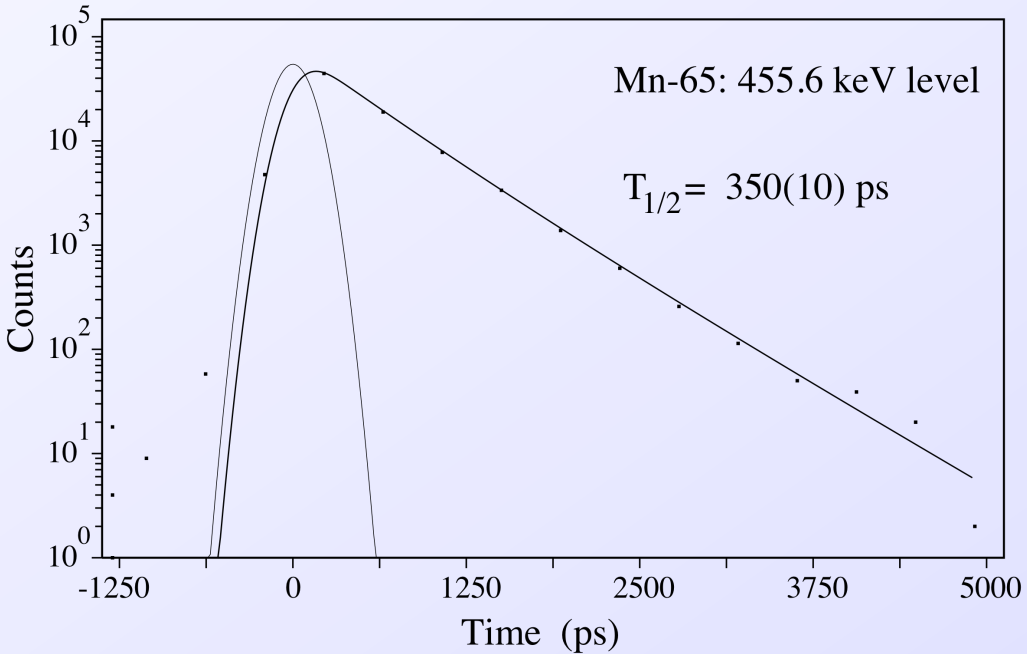
- ✓ New level scheme with 41 levels & 85 gamma-rays
- ✓ Precise energy of the β-decaying isomer
  → 393.7(2) keV
- ✓ $P_n = 7.9(12)\%$
  → Differs from previous 21.0(5)%
- ✓ $T_{1/2} = 91.9(9)$ ms for the g.s. of ^{65}Mn
  → consistent with previous 92(1) ms
- ✓

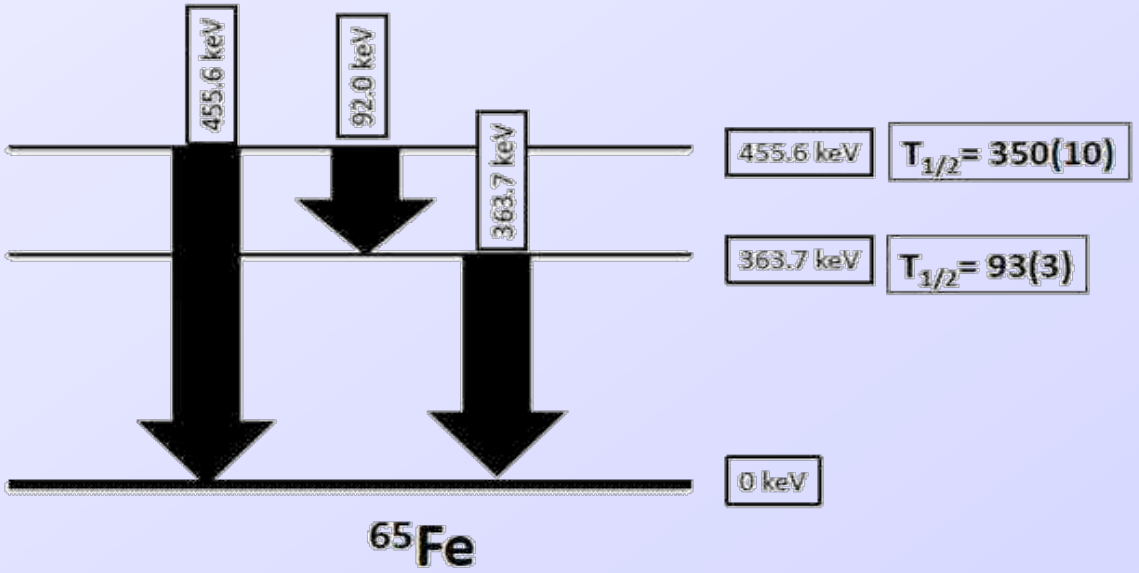
Level 363.7 keV	$T_{1/2} = 93(3)$ ps
Level 455.6 keV	$T_{1/2} = 350(10)$ ps
Level 561.0 keV	$T_{1/2} = 390(50)$ ps
Level 683.3 keV	$T_{1/2} = 24(10)$ ps

Fast-timing results









Spin/parity assignments: lifetimes and log*ft*

- ✓ Starting point

  → $J^\pi = 5/2^-$, g.s. in ^{65}Mn, $1/2^-$ g.s. and $9/2^+$ β-isomer in ^{65}Fe

- ✓ Level 363.7 keV $T_{1/2}$=93(3) ps **$J^\pi = 3/2^-$**

  → logft = 4.6 $J^\pi = 3/2^-, 5/2^-, 7/2^-$

  → γ-ray to $1/2^-$ .s. ~~E2 = 62(2) W.u. too high~~

  M1= 5 x 10^{-3} W.u. OK

- ✓ Level 455.6 keV $T_{1/2}$=350(10) ps **$J^\pi = 5/2^-$**

  ($3/2^-$ also possible)

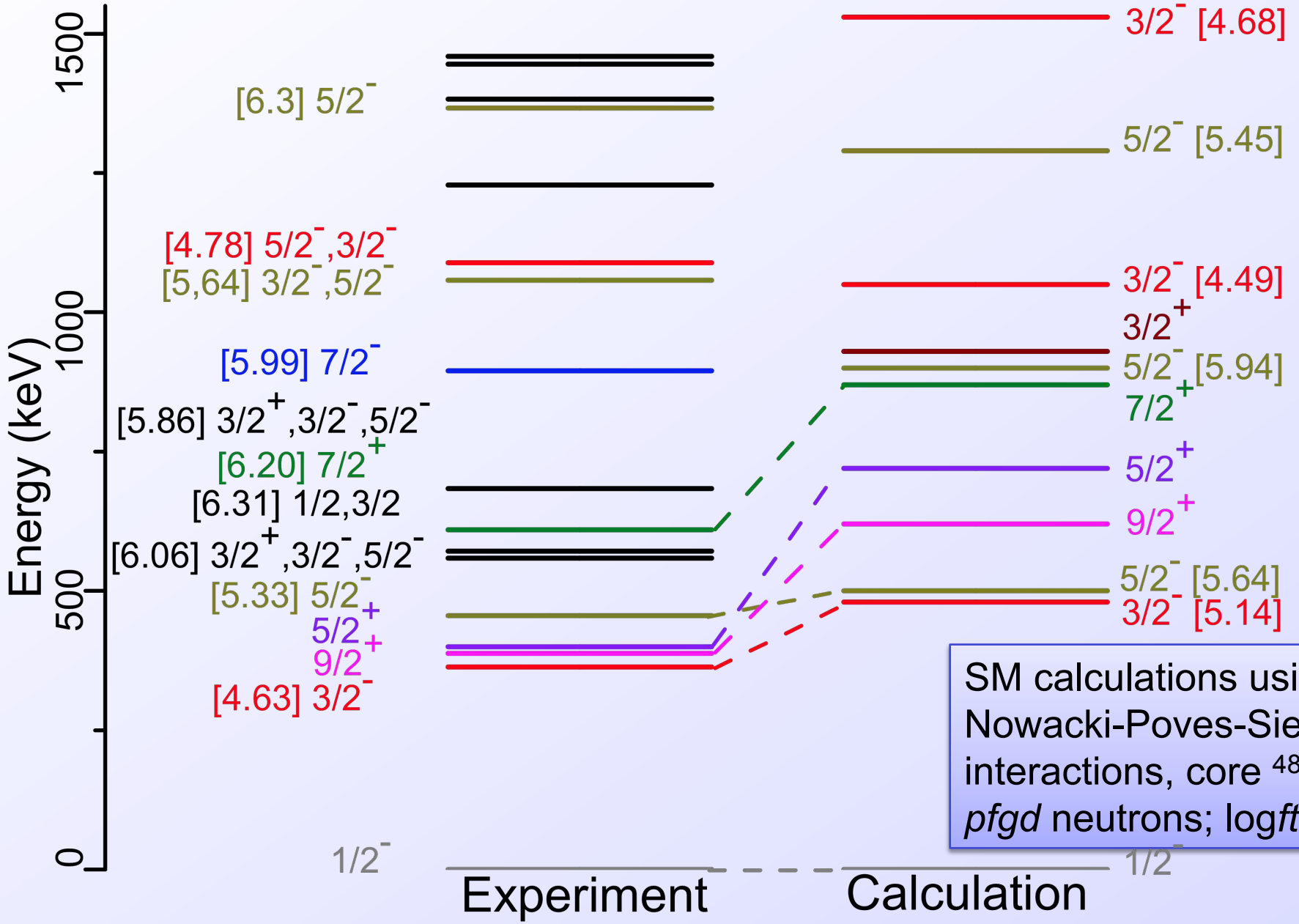
  → logft = 5.3 $J^\pi = 3/2^-, 5/2^-, 7/2^-$

  → γ-ray to $1/2^-$ g.s. E2 = 5.2(6) W.u. Or M1= 6.4(8) x 10-4 W.u. OK

  → γ-ray to $3/2^-$ 363.7 keV ~~E2 = 500 W.u. (huge!)~~

  M1= 2.5(4) x 10^{-3} W.u OK.

Calculations



SM calculations using Lenzi-Nowacki-Poves-Sieja (LNPS) eff. interactions, core ^{48}Ca, *pf* protons, *pfgd* neutrons; log*ft* in brackets.

IS474 main results

^{65}Fe: B. Olaizola *et al.* PRC88, 044306 (2013)
B. Olaizola *et al.*, AIP Conf. Proc. 1541 (2013) 181
^{63}Fe, ^{65}Fe, ^{66}Fe:
B. Olaizola, PhD Thesis, Universidad Complutense de Madrid, 2013
CERN-THESIS-2013-264
^{66}Fe: B. Olaizola *et al., "Structure of the N=40 nucleus ^{66}Fe"* prepared for submission

Data exist on the whole decay chains (taken in saturation)

Data taken also on A = 59, 60, 61, 62 and 64

Short test on ^{67}Mn decay, with ^{67}Ga contamination

IS474 – request for available shifts

- ✓ Complete fast-timing study on Fe isotopes and nuclei populated in the decay of heavy Mn.
- ✓ Picosecond lifetimes in ^{67}Fe and the A=67 decay chain.
  - → Spectroscopy expected from IS467 experiment
- ✓ Short test run to the decay of ^{68}Mn to ^{68}Fe
  - → feasibility of the fast-timing A=68 decay chain
  - → B(E2;$0^+ \rightarrow 2^+$) recently measured for ^{68}Fe, τ~60 ps for the 517 keV 2^+ state
- ✓ "Approved" IDS experiment on low-lying 0^+ and 2^+ states of ^{68}Ni

isotope	**yield (/uC)**	**target – ion source**	**Shifts (8h)**
^{67}Mn	100	UC_x - Ta(Nb) +RILIS (Mn) n converter	9
^{68}Mn	4	UC_x - Ta(Nb) + RILIS (Mn) n converter	2
^{24}Na, ^{140}Ba, ^{88}Rb	(high)	UC_x - Ta(Nb)	0.5

Ultra fast timing measurements at ^{78}Ni and ^{132}Sn

Addendum "Measurements on heavy Ga nuclei at N=50"

Spokesperson: H. Mach

→ Single particle features close to the doubly-magic ^{78}Ni

^{81}Ga = ^{78}Ni + 3p

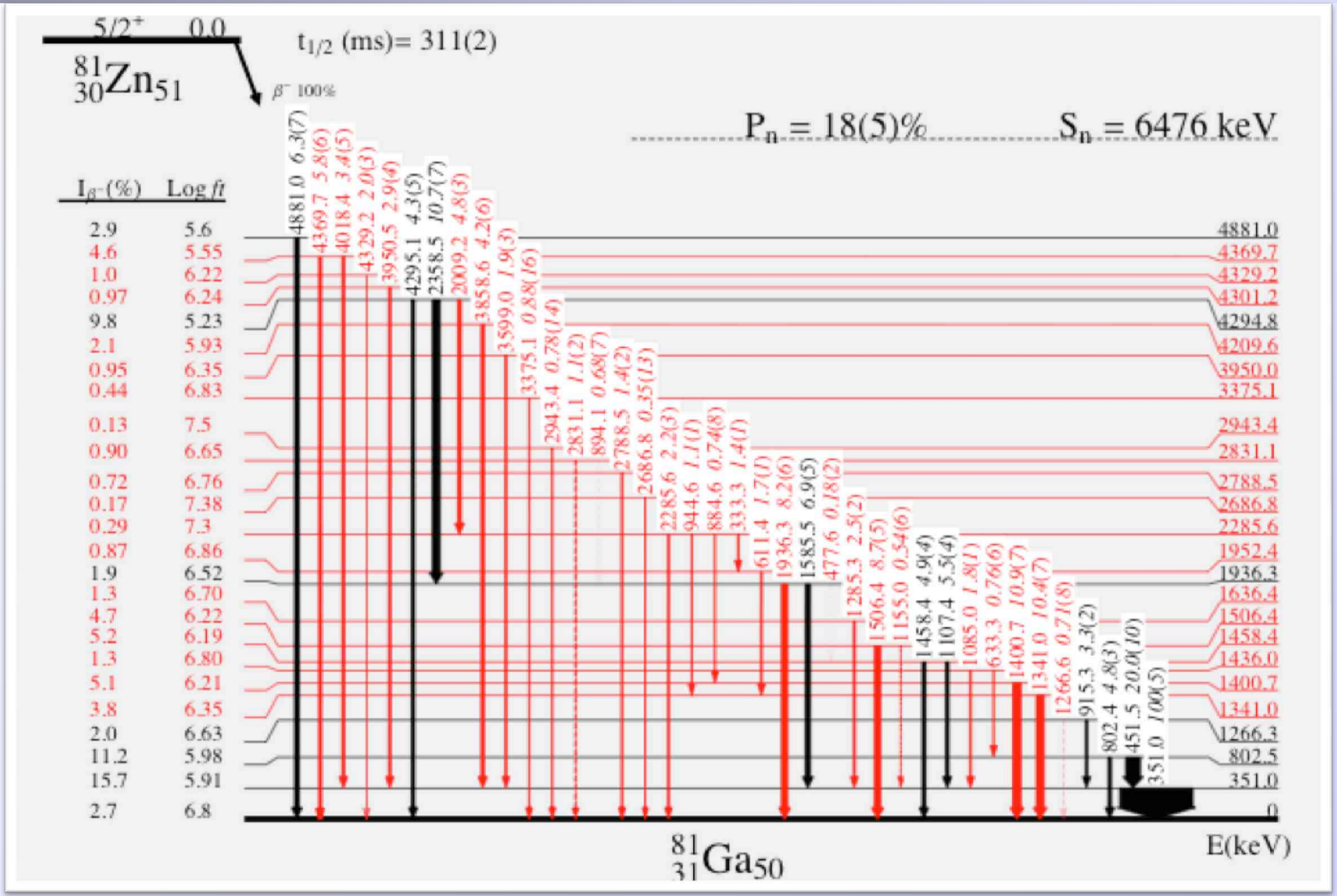
^{82}Ga = ^{78}Ni + 3p + n

^{80}Ga = ^{78}Ni + 3p – n

→ Slow M1 transitions and lifetimes in the sub-ns to ns range.

UC_x target, quartz transfer line, RILIS, HRS

IS441: example from ^{81}Zn decay



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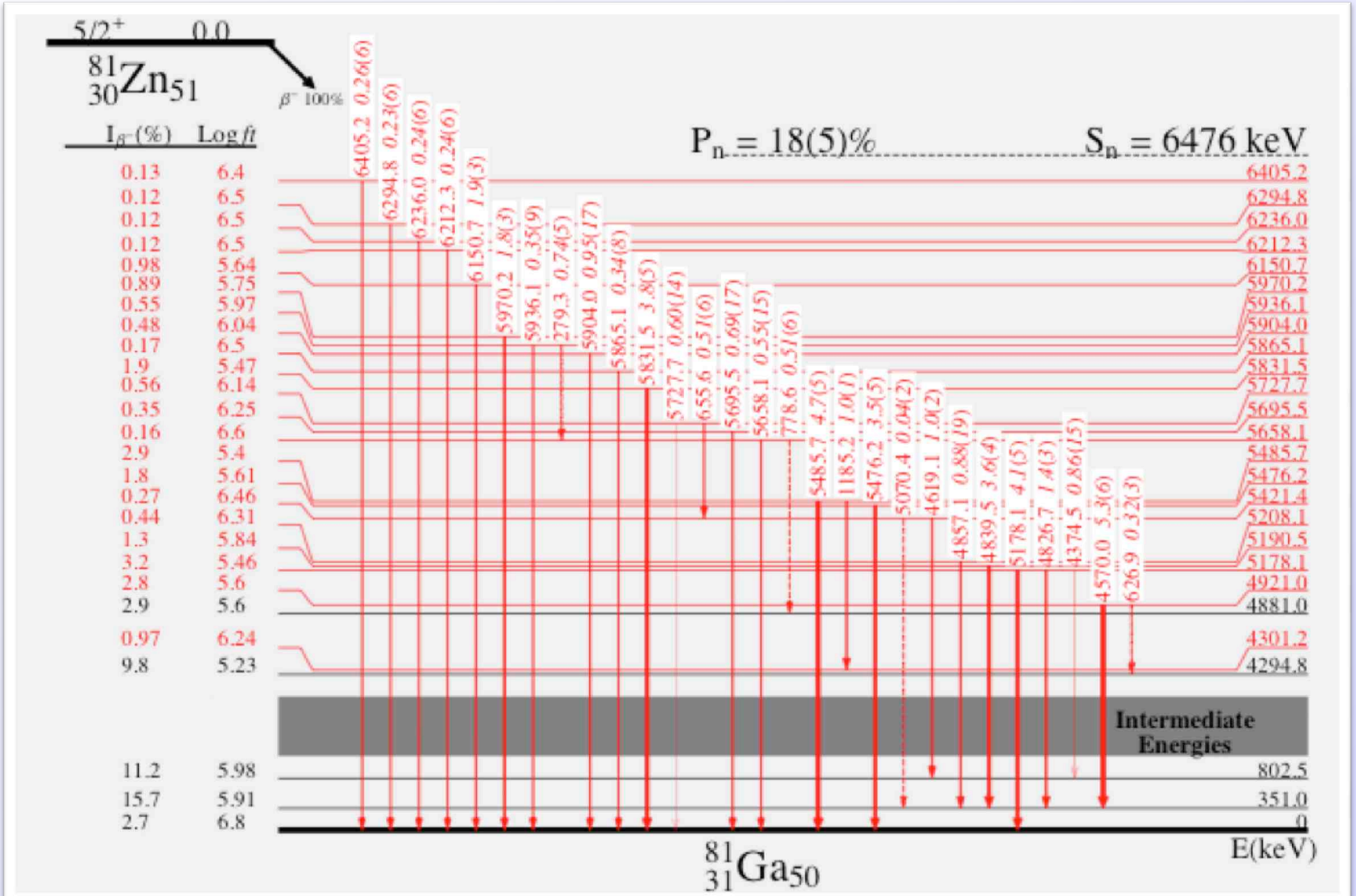
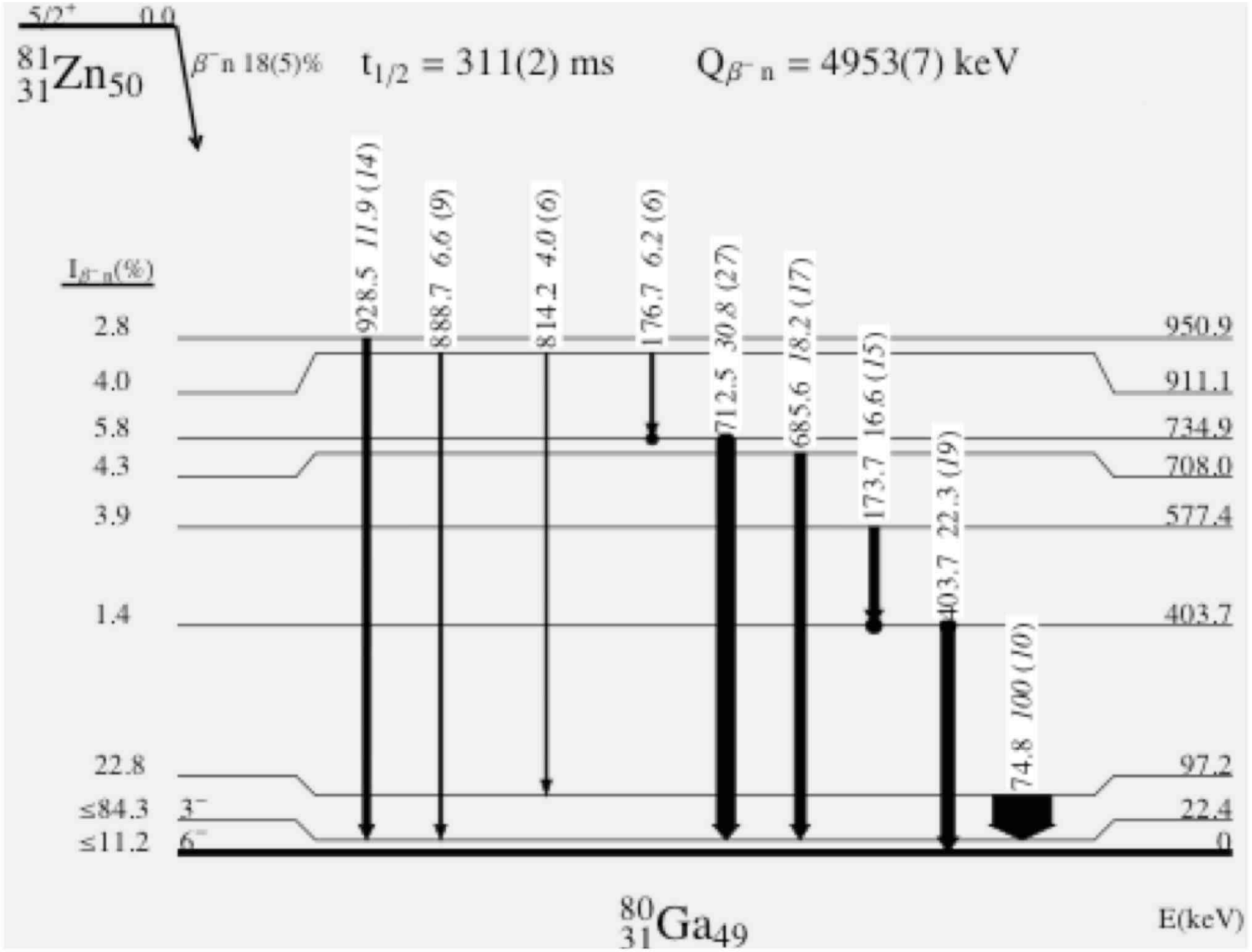


Level scheme of ^{80}Ga (β^-n)



V. Paziy et al.

^{80}Zn decay from R. Lica et al.

IS441 data

^{81}Ga from the beta decay of ^{81}Zn

- Zn beam leads to much higher statistics and sensitivity
- 40 new energy levels and 50 new gamma transitions
- P_n = 17(5)% (previous results 12(4)% and 30(13)%)
- New level scheme of ^{80}Ga populated by β-n from ^{81}Zn
- Fast timing analysis is underway, good prospects

V. Paziy, "Structure of ^{81}Ga populated from the β− decay of ^{81}Zn", *Master Thesis,* UCM 2012
V. Paziy, AIP Conf. Proc. 1541 (2013) 185

^{80}Ga from the beta decay of ^{80}Zn

- expanded level scheme
- low-lying isomeric state has been identified
- long lifetime ~20 ns of 685 keV

R. Lica *et al.*, AIP Conf. Proc. 1491 (2012) 97
R. Lica *et al.,* prepared for submission

^{82}Zn → ^{82}Ga

Low-lying isomeric state in ^{80}Ga from the β^- decay of ^{80}Zn

R. Lică[1], N. Mărginean[1], D.G. Ghiță[1], H. Mach[2,3], L.M. Fraile[2], A. Aprahamian[4], C. Bernards[5,6], J.A. Briz[7], B. Bucher[4], C.J. Chiara[8,9], Z. Dlouhý[10,*], I. Gheorghe[1], P. Hoff[11],

IS441 – future plans

- ✓ No available shifts
  - → Complete analysis, including fast timing

- ✓ Future proposal on ^{82}Zn decay to measure half-lives in ^{82}Ga
  - → better conditions (heavy Zn contaminated by ^{82}Rb and ^{81}Rb)
  - → extended beam time

- ✓ Future proposal on the decay of ^{80}Ga

IS441 and IS474 ISOLDE Collaborations

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Henryk Mach *NCBJ, Warsaw, Poland*

Ioana Gheorghe (^{82}Ga), D. Ghita, **Razvan Lica (^{80}Ga),** N. Marginean, R. Marginean, C. Petrone, T. Sava, M. Stanoiu, L. Stroe *NIPNE, Bucharest, Romania*

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P. Hoff *University of Oslo, Oslo, Norway*

Fin

Fast-timing results