

Coulomb Excitation  $^{74-80}\text{Zn}$  (N=50):  
probing the validity of shell-model  
descriptions around  $^{78}\text{Ni}$

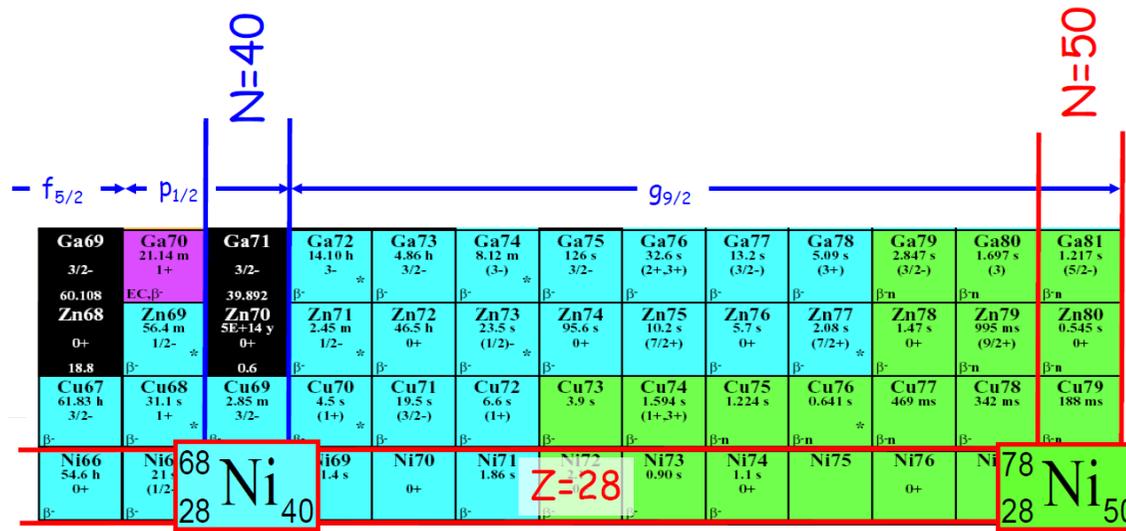




# The Physics Case

Nuclear-structure evolution from  $^{68}\text{Ni}$  towards  $^{78}\text{Ni}$

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Study effects of filling the positive parity  $g_{9/2}$  and  $d_{5/2}$  neutron orbitals near or at the Z=28

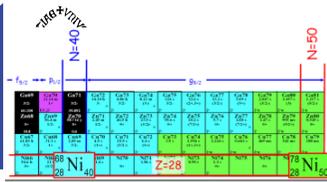
- ❑ What is the nature of the N=40 shell closure?
- ❑ How large is the N=50 shell gap at  $^{78}\text{Ni}$ ?
- ❑ What does the effective proton-neutron interaction look like ?

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# Physics Motivations

The region around Z=28 and between N=40 and N=50 is characterized:

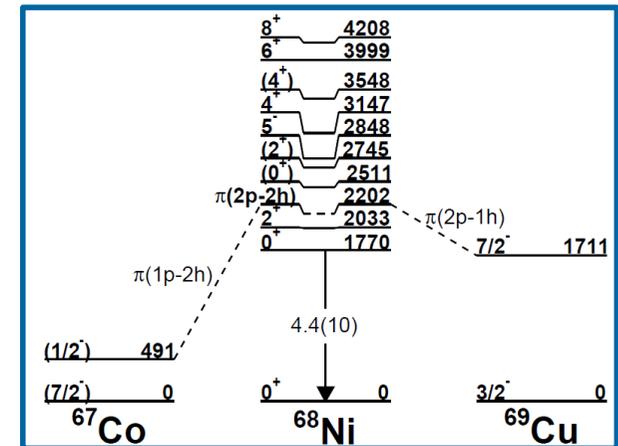
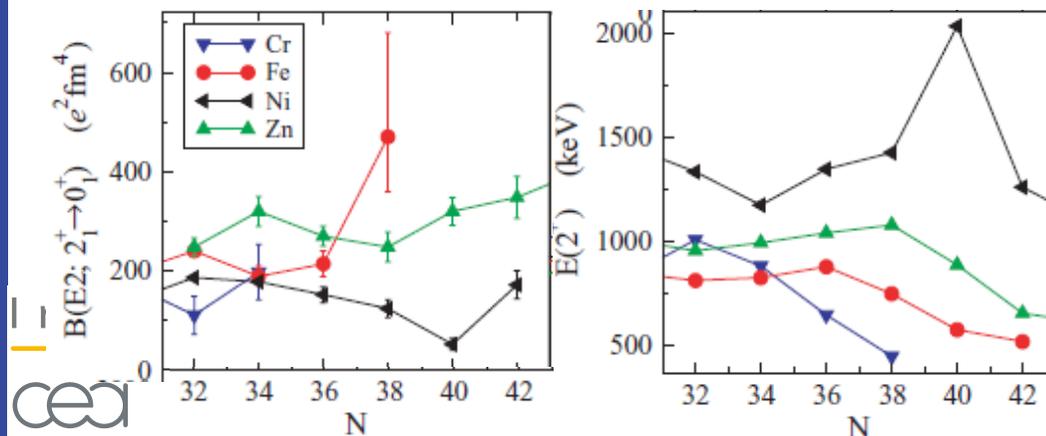
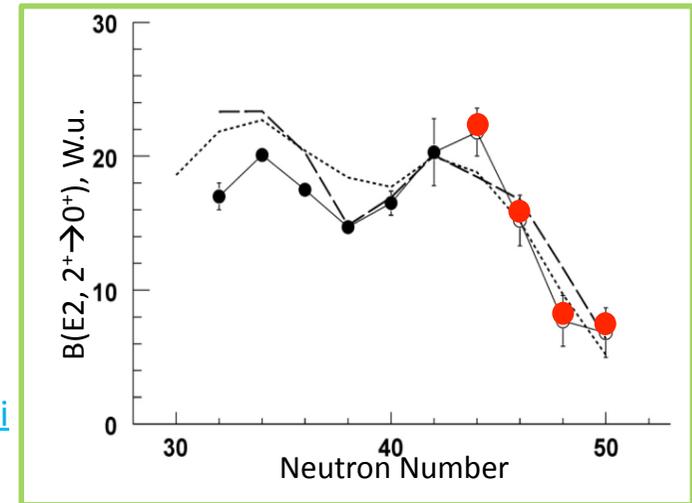
- Monopole migration of proton single particle states; collective states and proton intruder states in the n-rich Cu

Beta decay studies (S. Franchoo, PRL81 (1998));  
Laser spectroscopy (K. Flanagan, PRL103 (2009));  
Coulomb excitation (I. Stefanescu, PRL100 (2008))

- Restored N=50 shell at  $^{80}\text{Zn}$ : Coulomb excitation (J. Van de Walle, PRL99 (2007) 142501)

- Low-lying proton and neutron intruder states in and around  $^{68}\text{Ni}$  (D. Pauwels, PRC78 (2008) 041307(R) and PRC 82(2010))

- Swift onset of deformation below Z=28 (W. Rother PRL106 (2011) and A. Gade PRC81 (2010) )





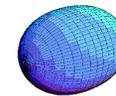
# Previous Experiment

Coulomb Excitation of  $^{74-80}\text{Zn}$  at ISOLDE

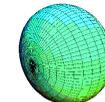
*J. Van de Walle et al., PRC 79, 014309 (2009)*

A	$B(E2, 2_1^+ \rightarrow 0_1^+)$	$B(E2, 4_1^+ \rightarrow 2_1^+)$	$\tau_{2_1^+}$
	$(e^2 \text{ fm}^4)$		
74	401(32)	507(74)	24.8(20)
76	290(36)	320(91)	36.4(46)
78	154(38)	—	25.5(61)
80	150(32)	—	0.74(16)
	144(29)	—	0.77(16)
	151(37)	—	0.73(18)
	138(43)	—	0.80(25)

- $A\text{Zn}$  on  $^{108}\text{Pd}/^{120}\text{Sn}$  at  $\approx 2.8$  MeV/u
- integral measurement
- excitation probability via normalization to target
- one observable:  $\sigma(2^+)$ , two unknowns:  $B(E2)$ ,  $Q_s$

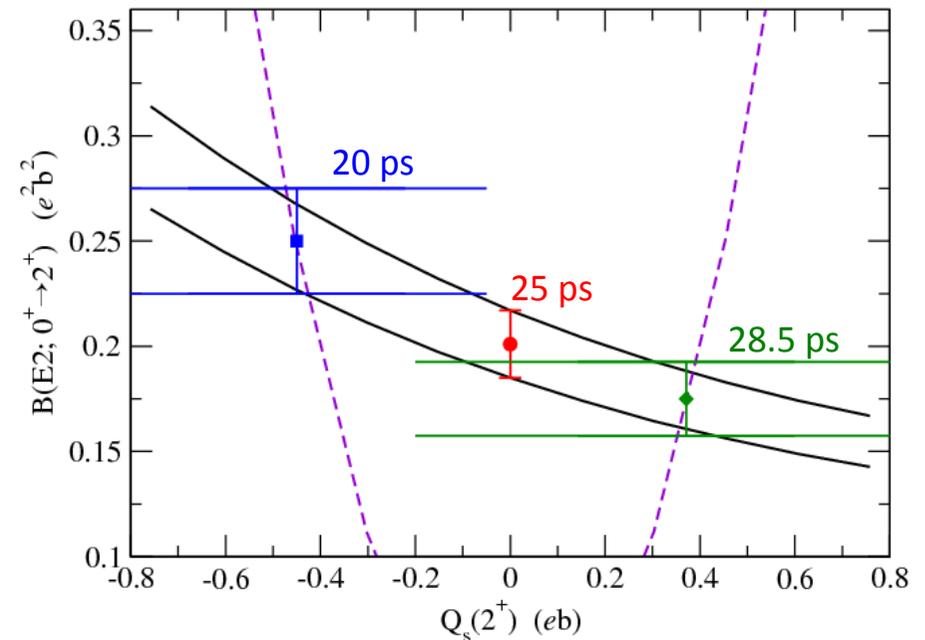
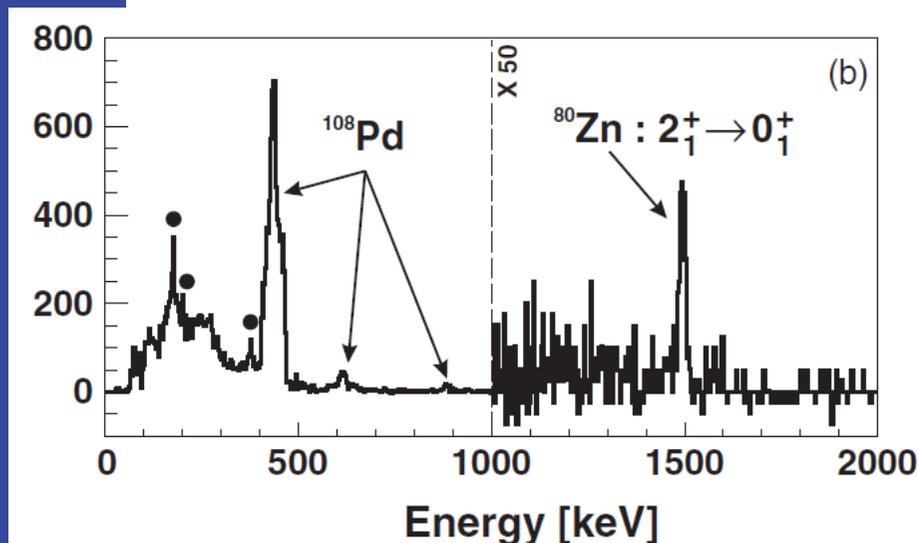


$^{74}\text{Zn}$



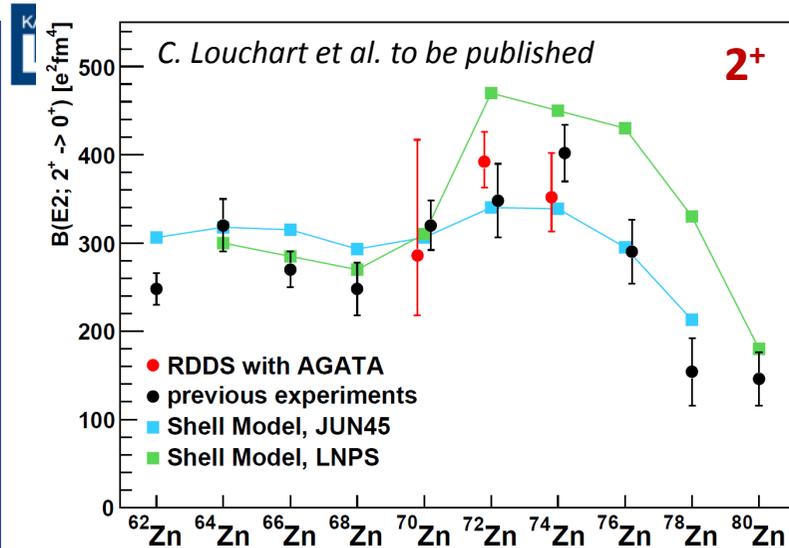
## First observation of the $2^+$ in $^{80}\text{Zn}$

*(J. Van de Walle et al., PRL99 (2007) 142501)*



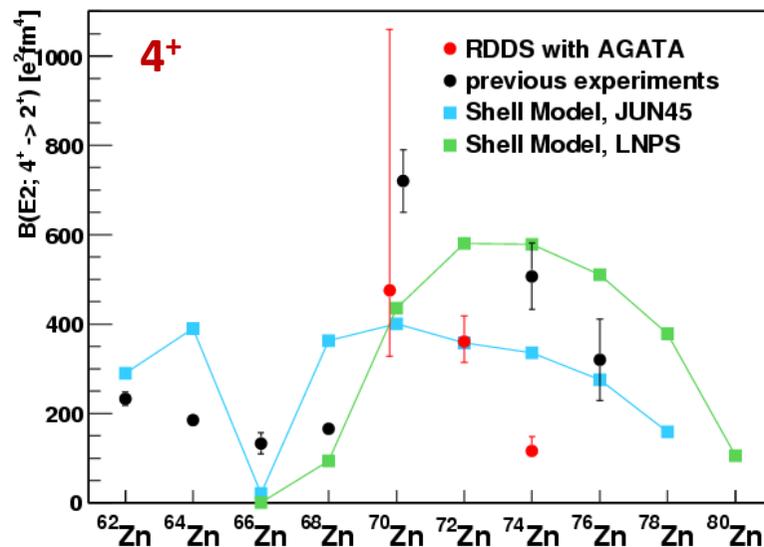
# Recent life-time Measurements

Recoil-Distance Doppler Shift (RDDS) experiments at Legnaro with AGATA



$^{70}\text{Zn}$ : D. Mücher et al. PRC 79 054310 (2009)  
 $^{74-80}\text{Zn}$ : J. Van de Walle et al. PRC 79 014309 (2009)

- ✓ Maximum of collectivity at  $N \sim 42$
- ✓  $B(E2; 2^+ \rightarrow 0^+)$  values in agreement with previous measurements



- ✓ lower  $B(E2; 4^+ \rightarrow 2^+)$  values with minimum at  $N=44$
- ✓ Discrepancy for  $\tau(4^+)$  in  $^{74}\text{Zn}$  with previous Coulomb excitation measurement



# Proposed Experiment

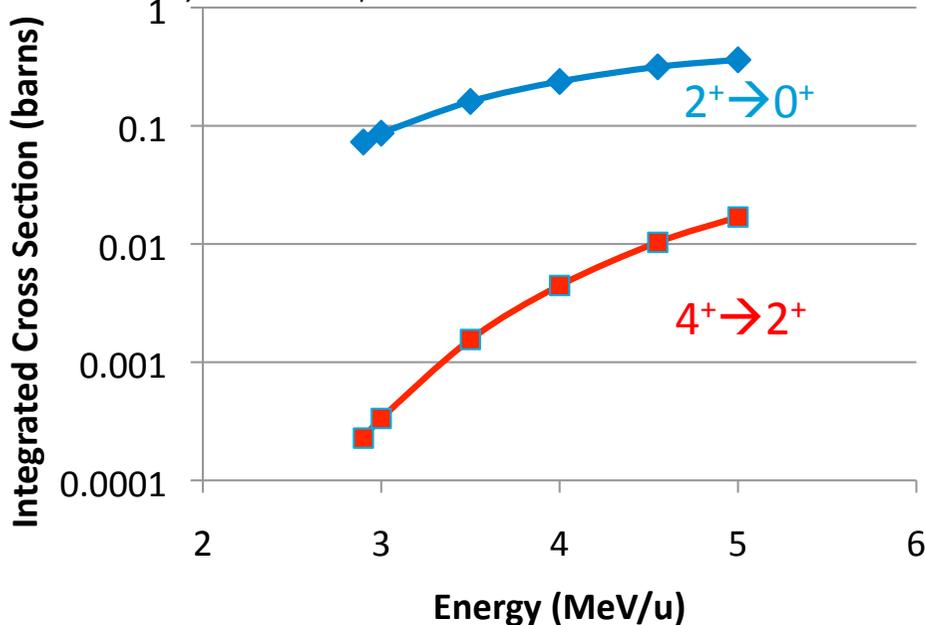
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## Coulomb Excitation of $^{74-80}\text{Zn}$ at HIE-ISOLDE

✓ Larger Cross-Sections of Multi-step Coulomb Excitation at higher energies (still in the safe Coulex regime)

➔ high-lying states can be more efficiently populated

Thanks: Katarzyna Wrzosek-Lipska



### AIM

- Extract the  $B(E2; 4^+ \rightarrow 2^+)$ ,  $B(E2; 6^+ \rightarrow 4^+)$  in  $^{74-78}\text{Zn}$
- Clarify the discrepancy with life-time measurements
- Observation of the  $4^+$  state in  $^{80}\text{Zn}$
- Depending on the collectivity, extract the  $B(E2; 4^+ \rightarrow 2^+)$  in  $^{80}\text{Zn}$
- Identification of low lying no-yrast states ( $0_2^+$ ,  $2_2^+$ )

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# Beam time Request



UC Target + quartz transfer line

- Expected Zn intensity:  $10^6 - 10^4$  pps
- Laser Ionization: RILIS
- Expected Ga and Rb contamination
- Beam energy 4.55 MeV/u corresponding to 95% of the safe energy
- We request therefore:

GOSIA calculations (Katarzyna Wrzosek-Lipska)

INPUT: - experimental data where available ♪  
 - Shell Model Calculations (\*)♪

Number of expected counts per shift

isotope	Energy (MeV/u)	Intensity (pps)	$2^+ \rightarrow 0^+$	$4^+ \rightarrow 2^+$	$6^+ \rightarrow 4^+$	Total shifts
$^{74}\text{Zn}$	4.55	$5 \cdot 10^5$	$6.9 \cdot 10^4$	2235	n.n.	3
$^{76}\text{Zn}$	4.55	$5 \cdot 10^5$	$5.4 \cdot 10^4$	1470	n.n.	3
$^{78}\text{Zn}$	4.55	$10^5$	5100	37(**)	0.15 (**)	12
$^{80}\text{Zn}$	4.55	$10^4$	130	20 (*)	0.00012 (*)	12

Need **30 shifts** measurement

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# Collaboration

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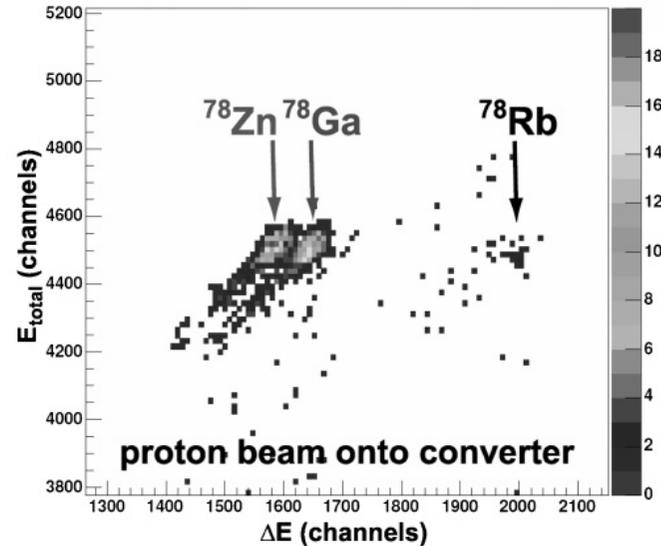
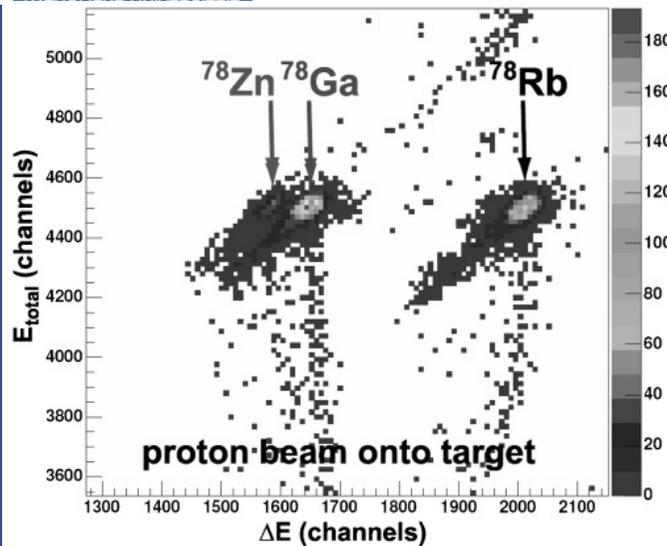
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# Previous Experiment

## Beam Composition and characterization



When ions are produced by neutron-induced fission of uranium

→ Large suppression of Rb

### QUARTZ transfer line

Only during A=80 experiment

- ✓ Absorbs a major part of the largely produced and surface ionized  $^{80}\text{Rb}$ ;
- ✓ High energy proton-induced fission
- ✓ Three time higher yields compared to the use of converter neutron-induced fission

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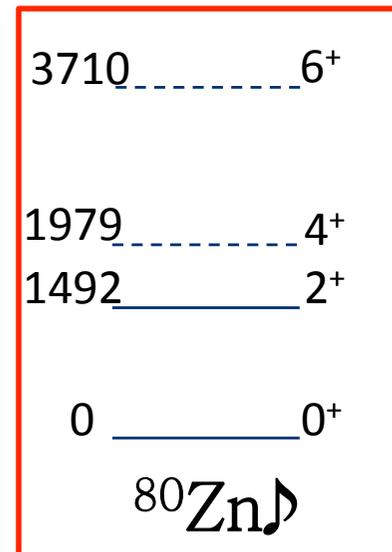
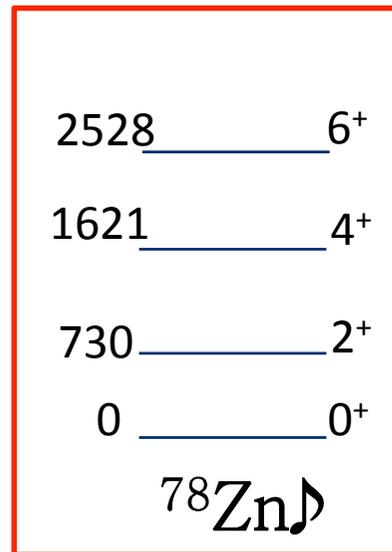
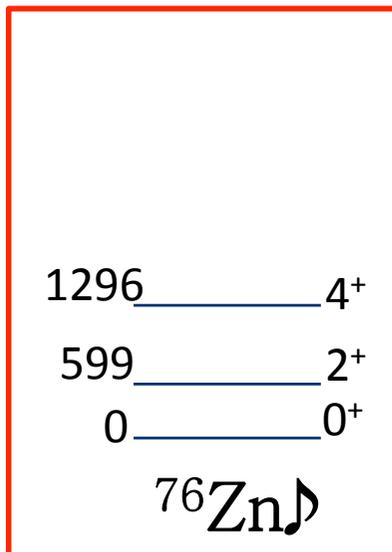
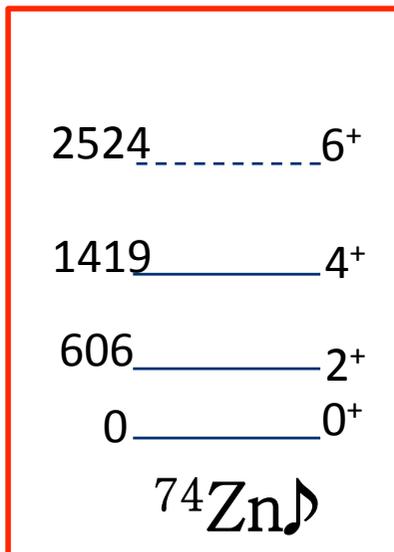


# Some estimations



GOSIA calculations

INPUT: - experimental data where available ♪  
- Shell Model Calculations ♪



K. Sieja and F. Nowacki Private Communication

INITIAL STATE 2\*J= 4 N= 1 2<sup>+</sup> → 0<sup>+</sup>  
 QUAD. MT= -39.65765596  
 FINAL STATE 2\*J= 0 N= 1 DE= 0.518 BE(L)= 445.68479719

INITIAL STATE 2\*J= 8 N= 1 4<sup>+</sup> → 2<sup>+</sup>  
 QUAD. MT= -48.52883644  
 FINAL STATE 2\*J= 4 N= 1 DE= 0.849 BE(L)= 610.15453871

INITIAL STATE 2\*J=12 N= 1 6<sup>+</sup> → 4<sup>+</sup>  
 QUAD. MT= -46.88766440  
 FINAL STATE 2\*J= 8 N= 1 DE= 1.157 BE(L)= 513.33825537

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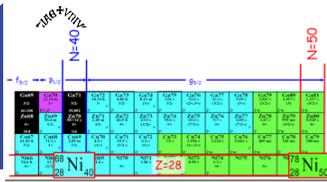


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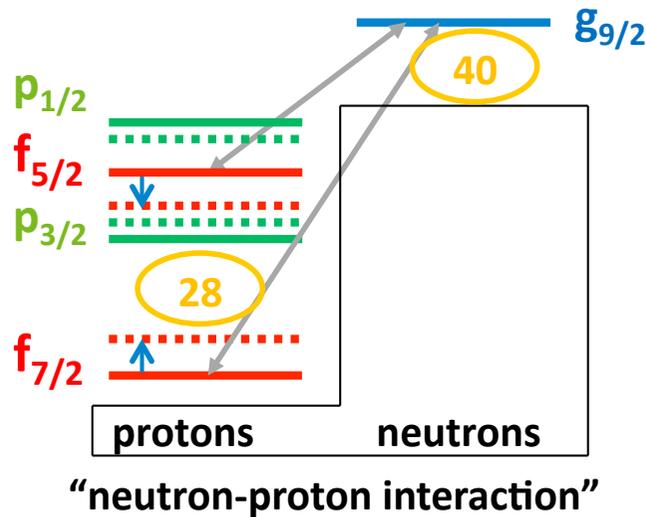
A	Zn/Total (%)		$B(E2, 2_1^+ \rightarrow 0_1^+)$	$B(E2, 4_1^+ \rightarrow 2_1^+)$	$\tau_{2_1^+}$	$E(2_1^+)$	$E(4_1^+)$	Measuring time		
	ON/OFF	ON	$(e^2 \text{ fm}^4)$		(ps)	(keV)	(keV)	ON	ON/OFF	OFF
74	82(1)	83(4)	401(32)	507(74)	24.8(20)	606	813	8.5 h	3 h	–
76	79(2)	73(7)	290(36)	320(91)	36.4(46)	599	697	11.5 h	2.5 h	–
78	65(2)	64(13)	154(38)	–	25.5(61)	730	(891)	23 h	9 h	–
80	61(5) <sup>a</sup>	–	150(32)	–	0.74(16)	1492	–	102 h	6.5 h	6.5 h
	44(5) <sup>b</sup>	–	144(29)	–	0.77(16)					
	–	61(6) <sup>a</sup>	151(37)	–	0.73(18)					
	–	46(9) <sup>b</sup>	138(43)	–	0.80(25)					



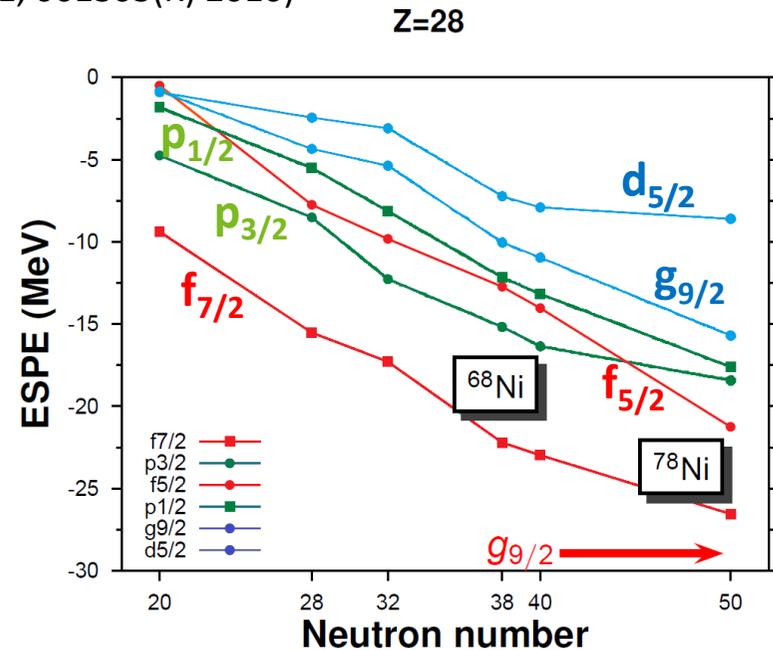
# Physics Motivations



“Shell quenching in  $^{78}\text{Ni}$ : a hint from the structure of neutron rich copper isotopes”  
 (K. Sieja and F. Nowacki, Phys. Rev. C 81, 061303(R) 2010)



T. Otsuka et al. Phys. Rev. Lett. 95, 232502 (2006)



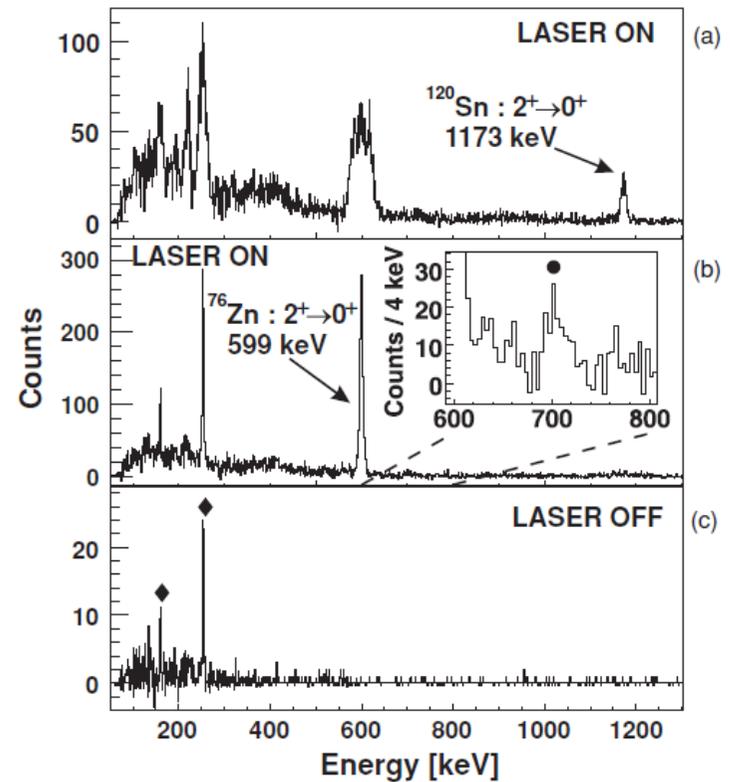
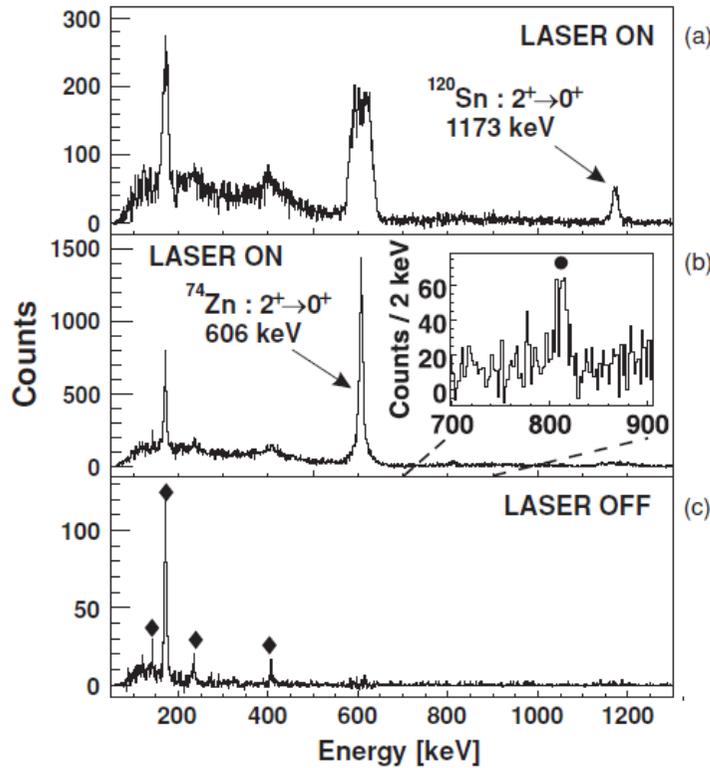
- ❑ Reduction of the proton  $f_{5/2} - f_{7/2}$  gap when filling neutron  $g_{9/2}$  orbital
- ❑ Crossing of proton  $f_{5/2} - p_{3/2}$  orbitals in the mid-shell (monopole migration)

- Different proton-neutron residual interactions have been proposed (realistic G-matrix + monopole adjustment (USD, KB3, GXPF1, JUN45, jj4b, etc..))
- Level across the Z=28, N=40 and N=50 gaps: role of the correlations



# Previous Experiment

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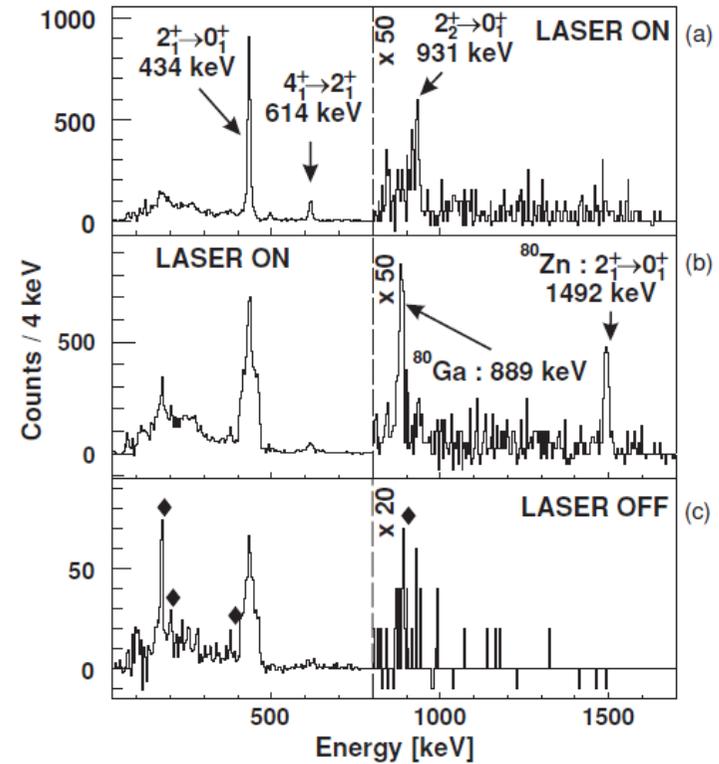
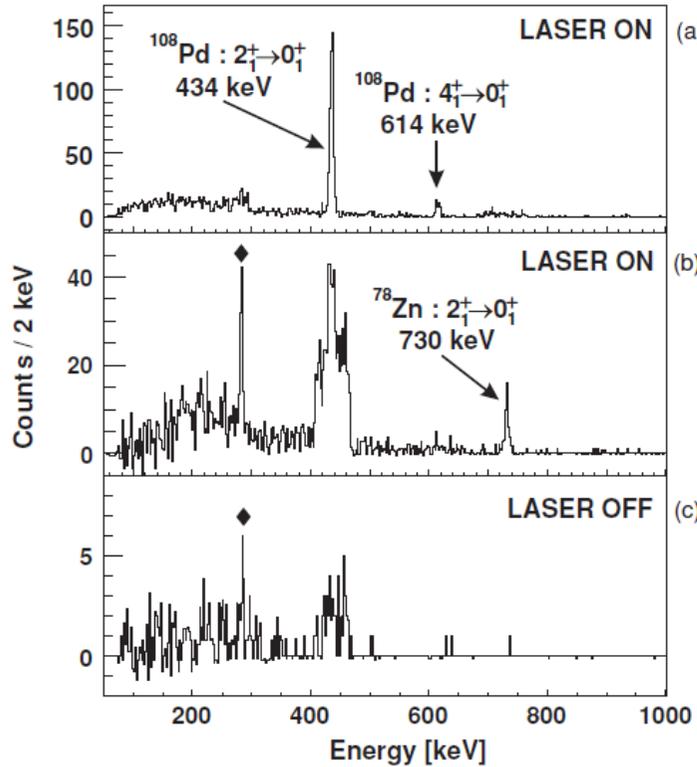
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