Probing nuclear structure and deformation in the vicinity of ^{40}Ca and ^{56}Ni

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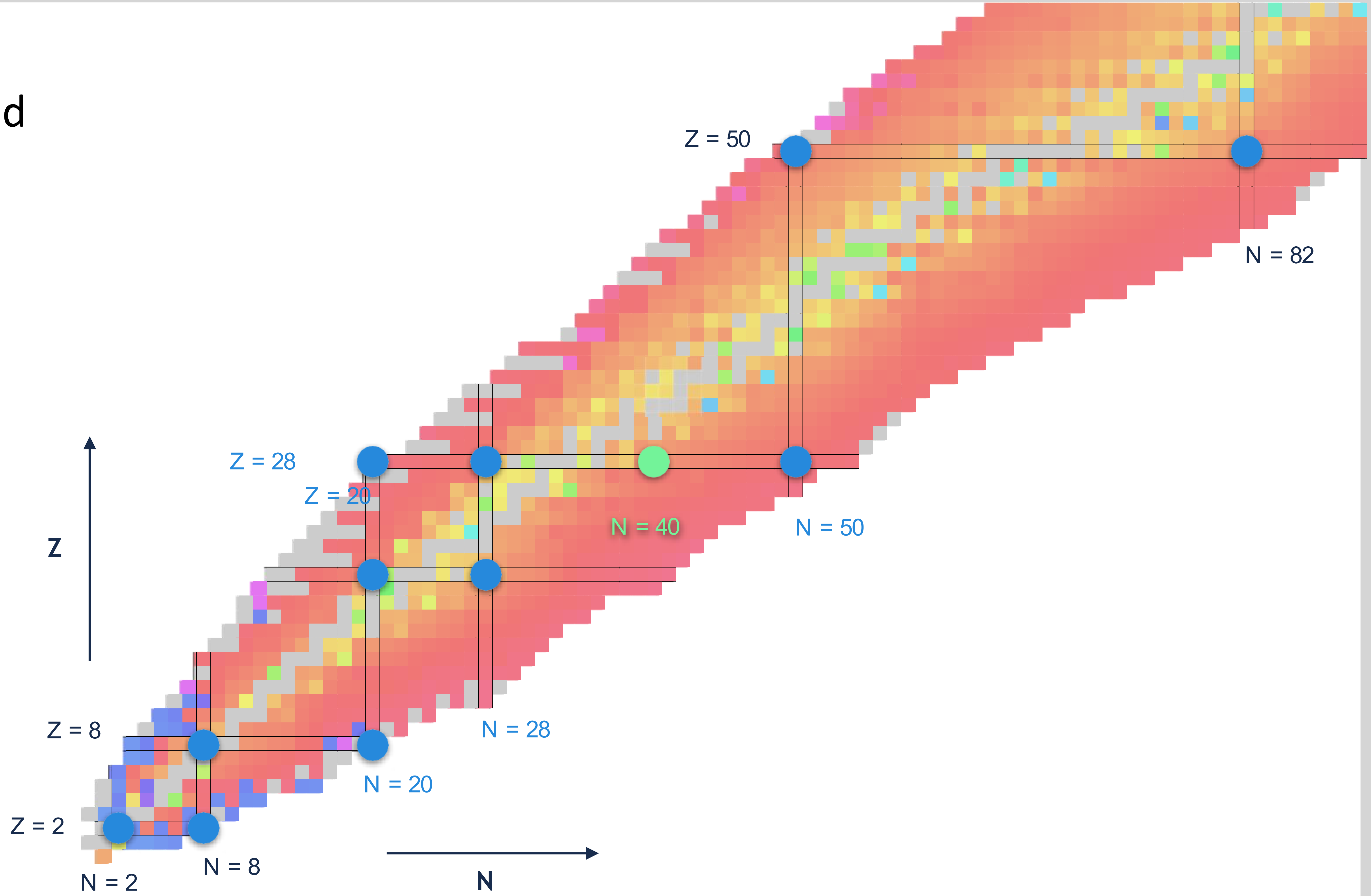
Faculty of Physics, University of Warsaw

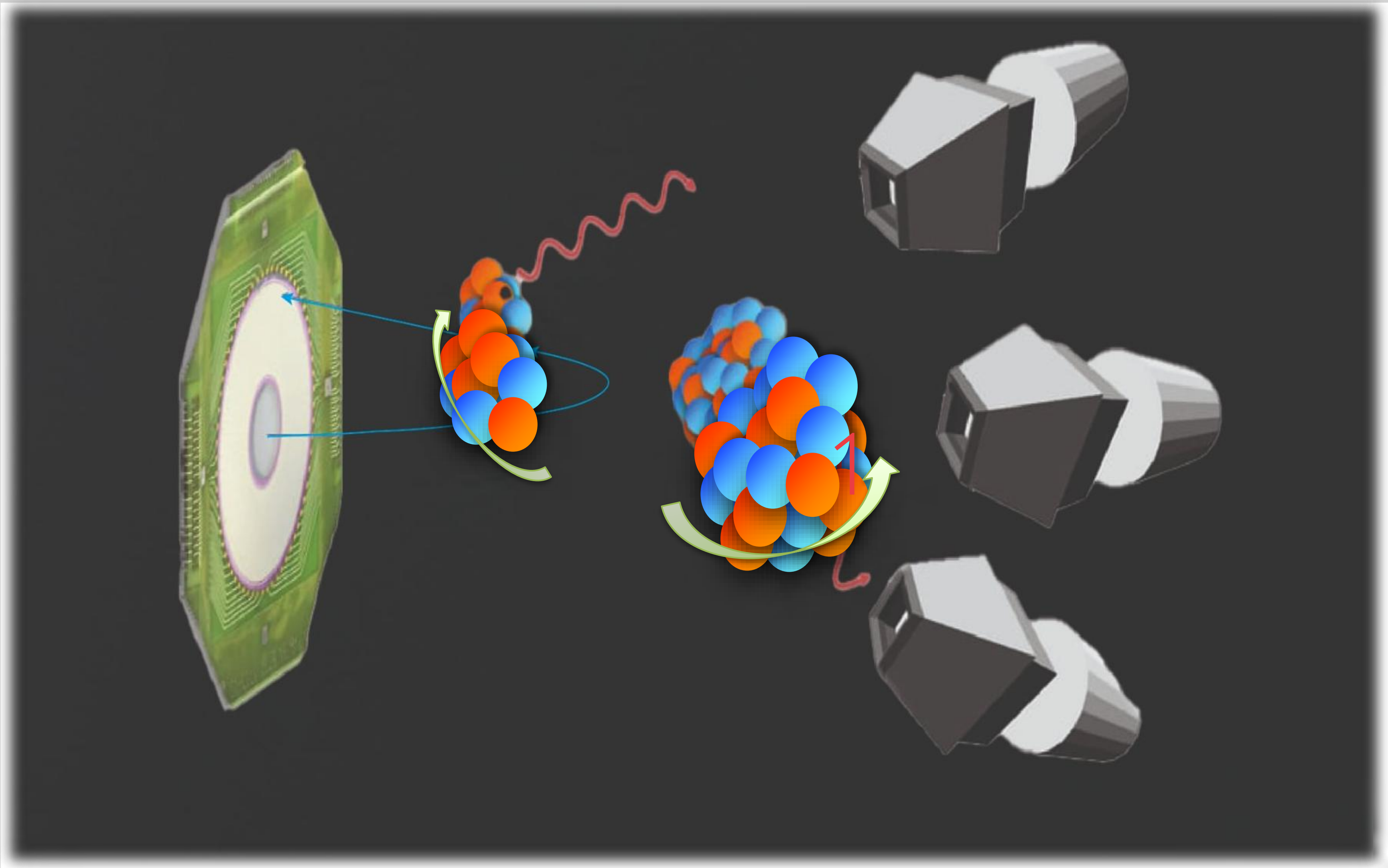
2/10/2025

Outline

- ➢Coulomb excitation method
- ➢^{40}Ca region
- ➢^{56}Ni region
- ➢To-do list



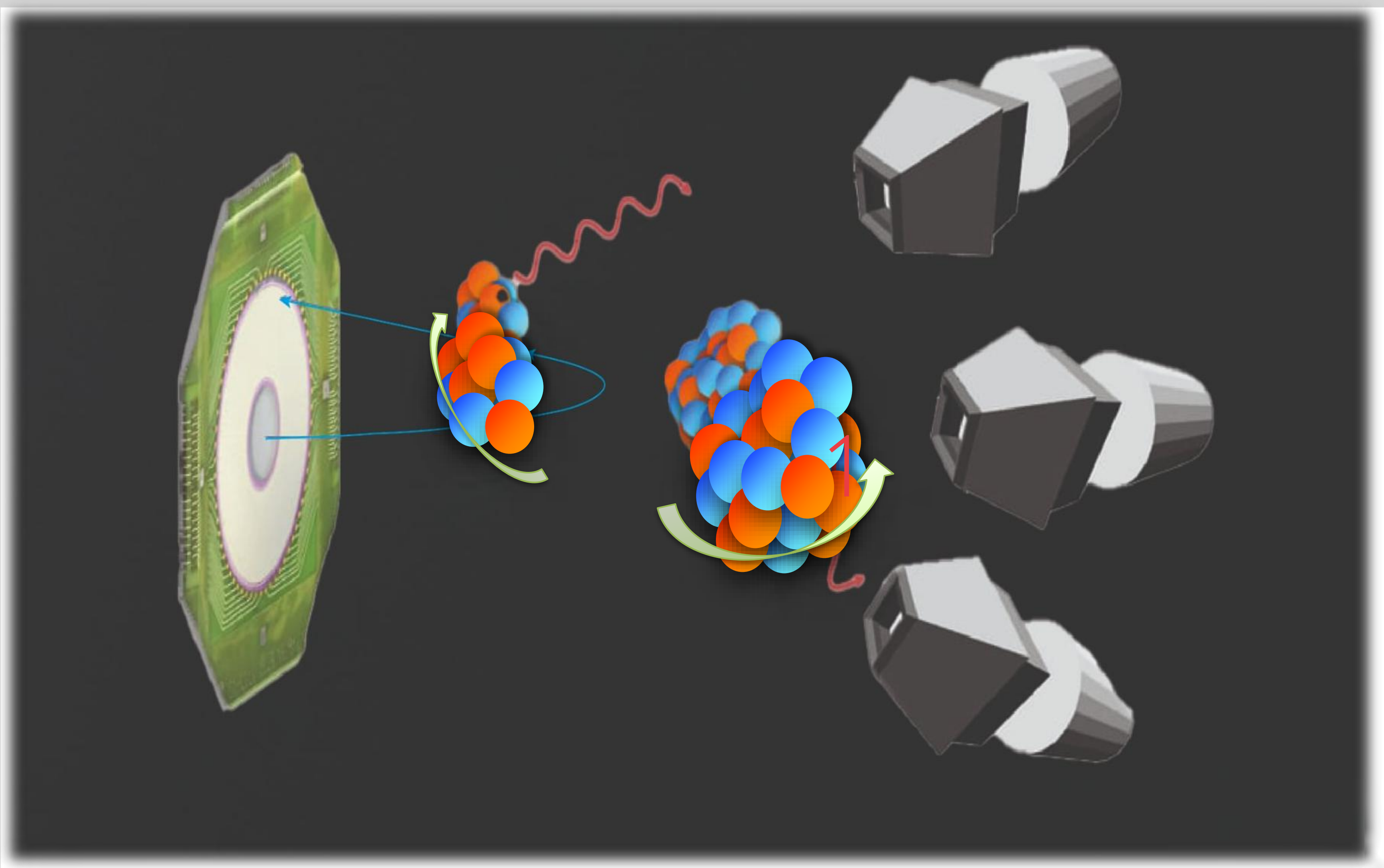
Coulomb excitation (in a nutshell)

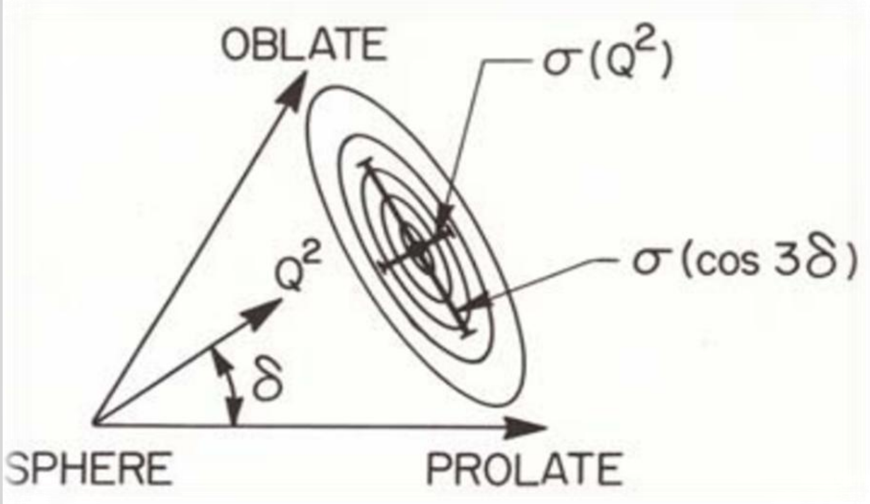


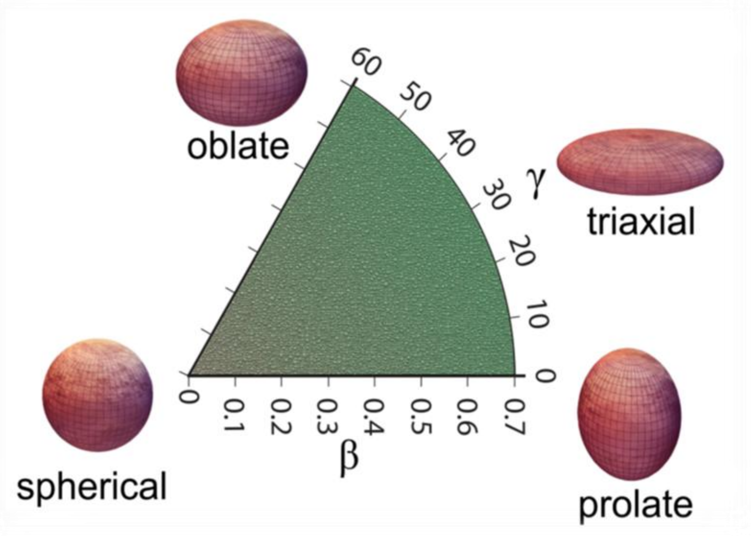
$$D_{min} = 1.25 \cdot (A_p^{1/3} + A_t^{1/3}) + 5.0 \quad [fm]$$

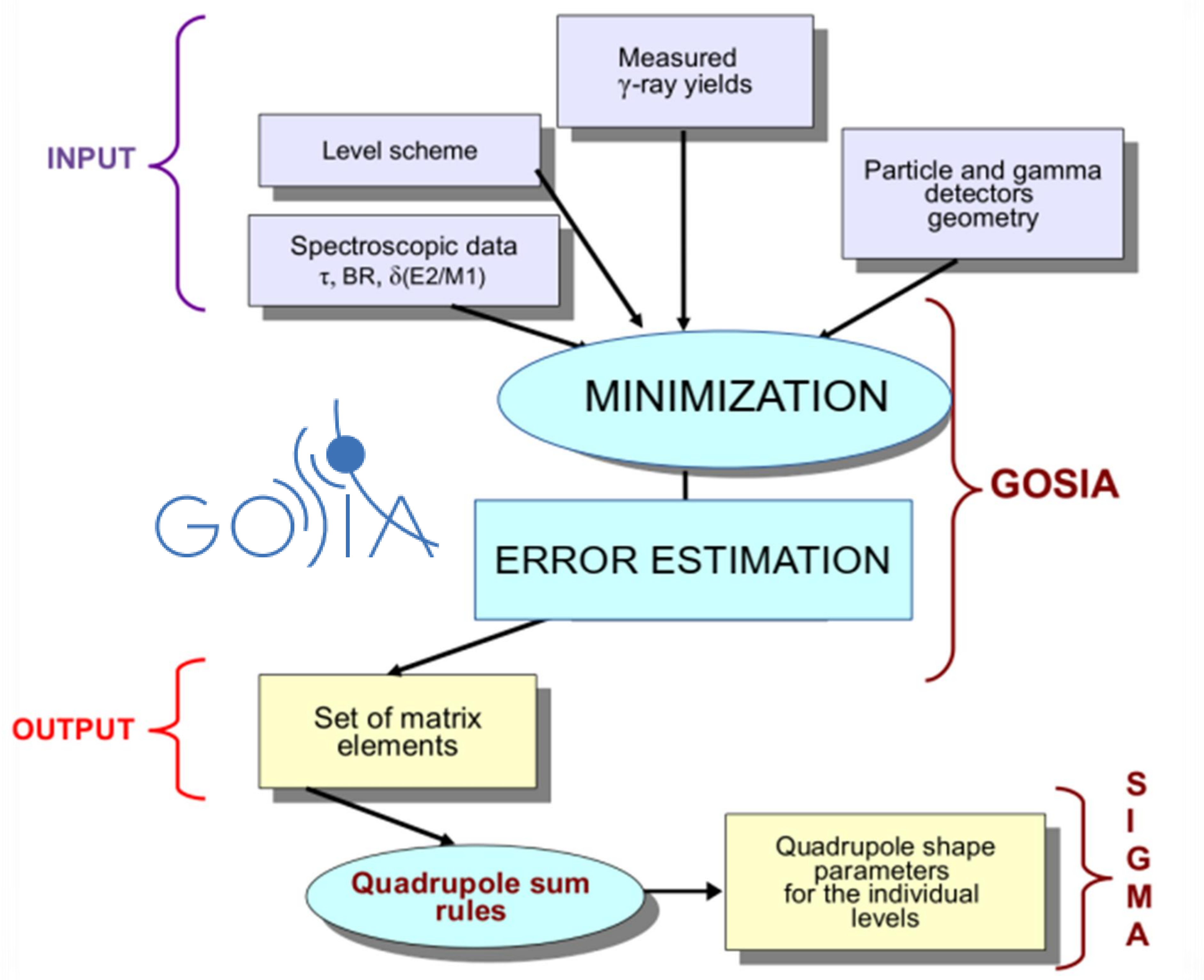
$$E_{max}(\theta_{CM}) = 0.72 \cdot \frac{A_p + A_t}{A_t} \cdot \frac{Z_p \cdot Z_t}{D_{min}} \cdot \left(1 + \frac{1}{\sin\left(\frac{\theta_{CM}}{2}\right)}\right) \quad [MeV]$$

Coulomb excitation (in a nutshell)





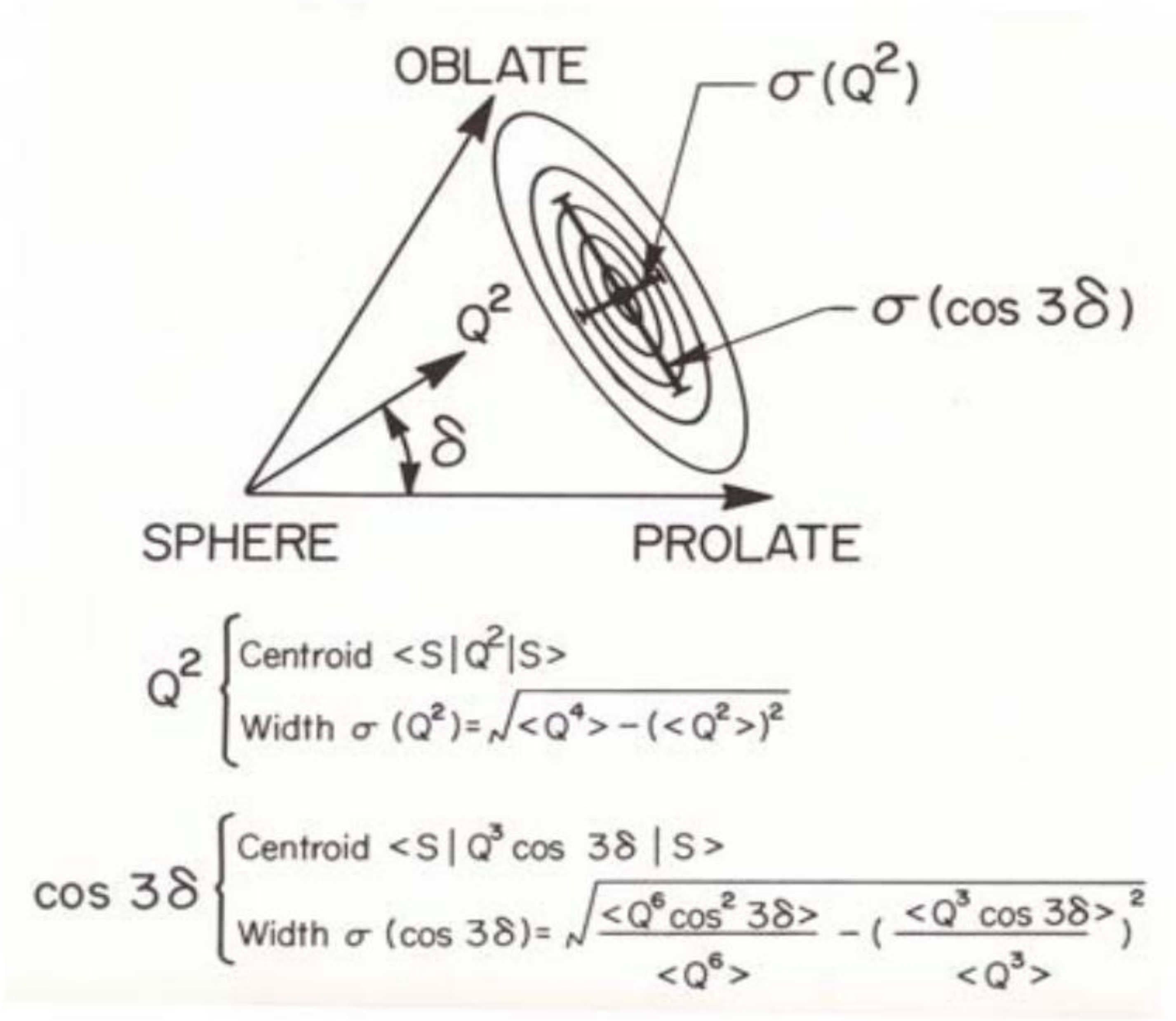




result:

a set of matrix elements – including the diagonal ME (Q*s*) – with their relative signs

Shape invariants

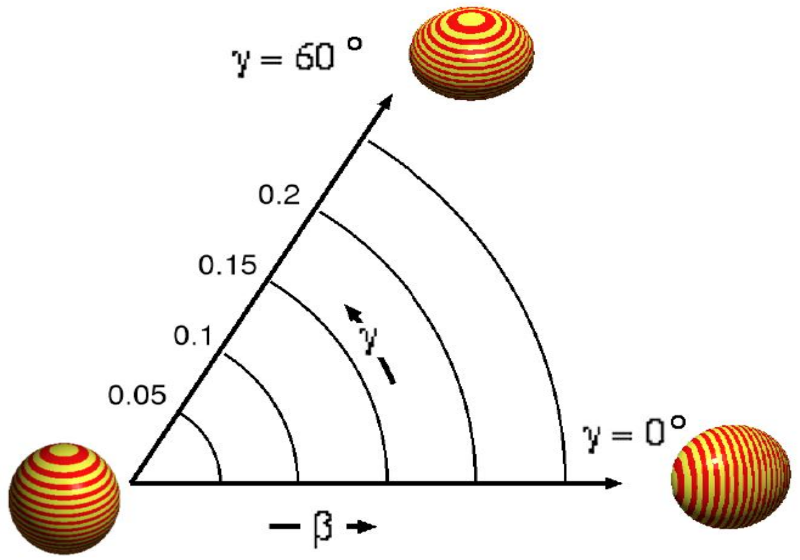


$$\frac{1}{\sqrt{5}}\langle Q^2\rangle = \frac{1}{\sqrt{2I_i+1}}\sum_t \langle i\|E2\|t\rangle\langle t\|E2\|f\rangle \begin{Bmatrix} 2 & 2 & 0 \\ I_i & I_f & I_t \end{Bmatrix}$$

$$\langle Q^3\cos(3\delta)\rangle = \mp\frac{\sqrt{35}}{\sqrt{2}}\frac{1}{\sqrt{2I_i+1}}\sum_{tu}\langle s\|E2\|u\rangle\langle u\|E2\|t\rangle\langle t\|E2\|s\rangle \begin{Bmatrix} 2 & 2 & 2 \\ I_s & I_t & I_u \end{Bmatrix}$$

$$\beta = \sqrt{\langle\beta^2\rangle} = \sqrt{\frac{\langle Q^2\rangle}{q_0^2}},$$

$$\gamma = \arccos\langle\cos(3\delta)\rangle,$$

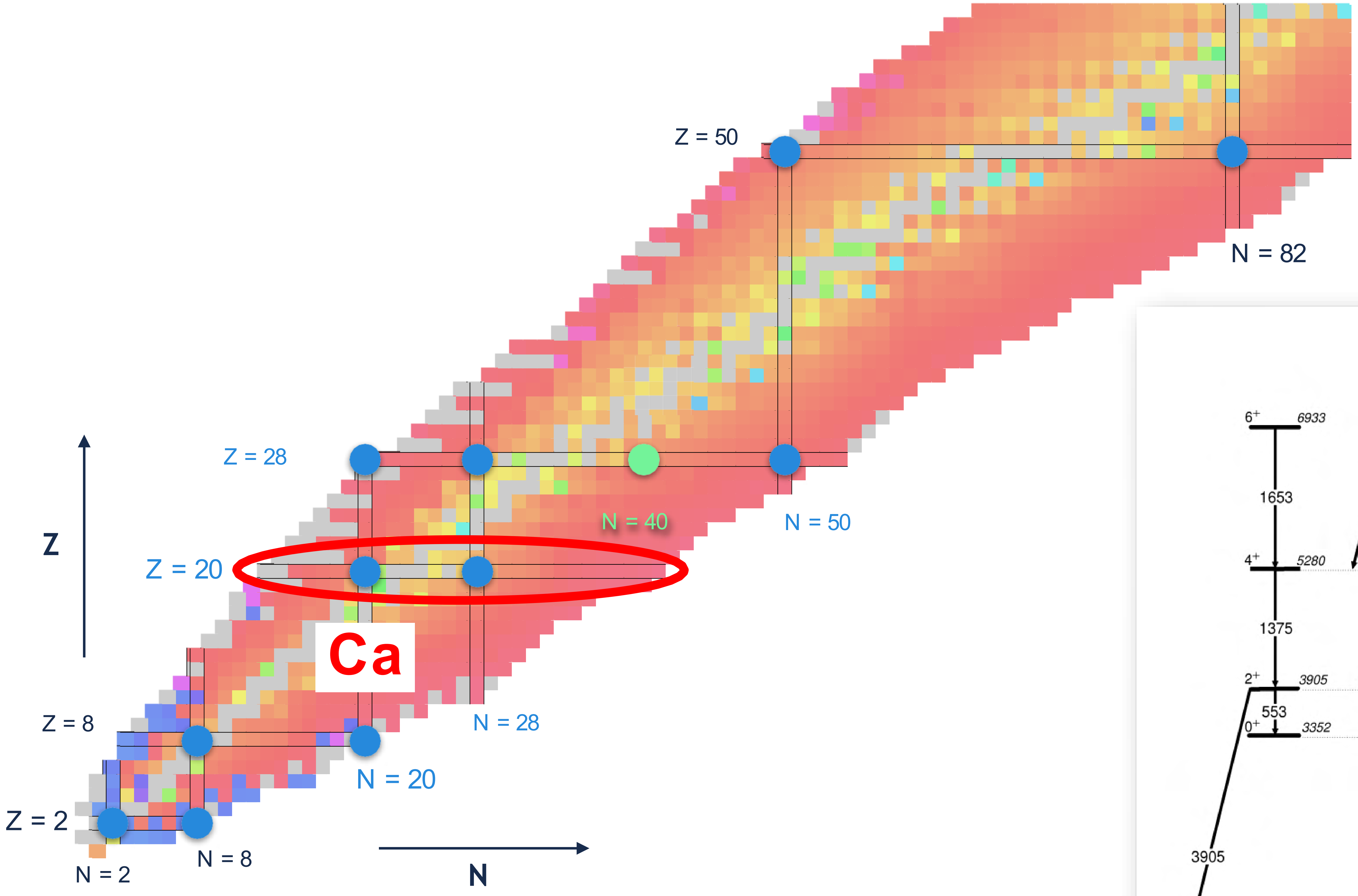


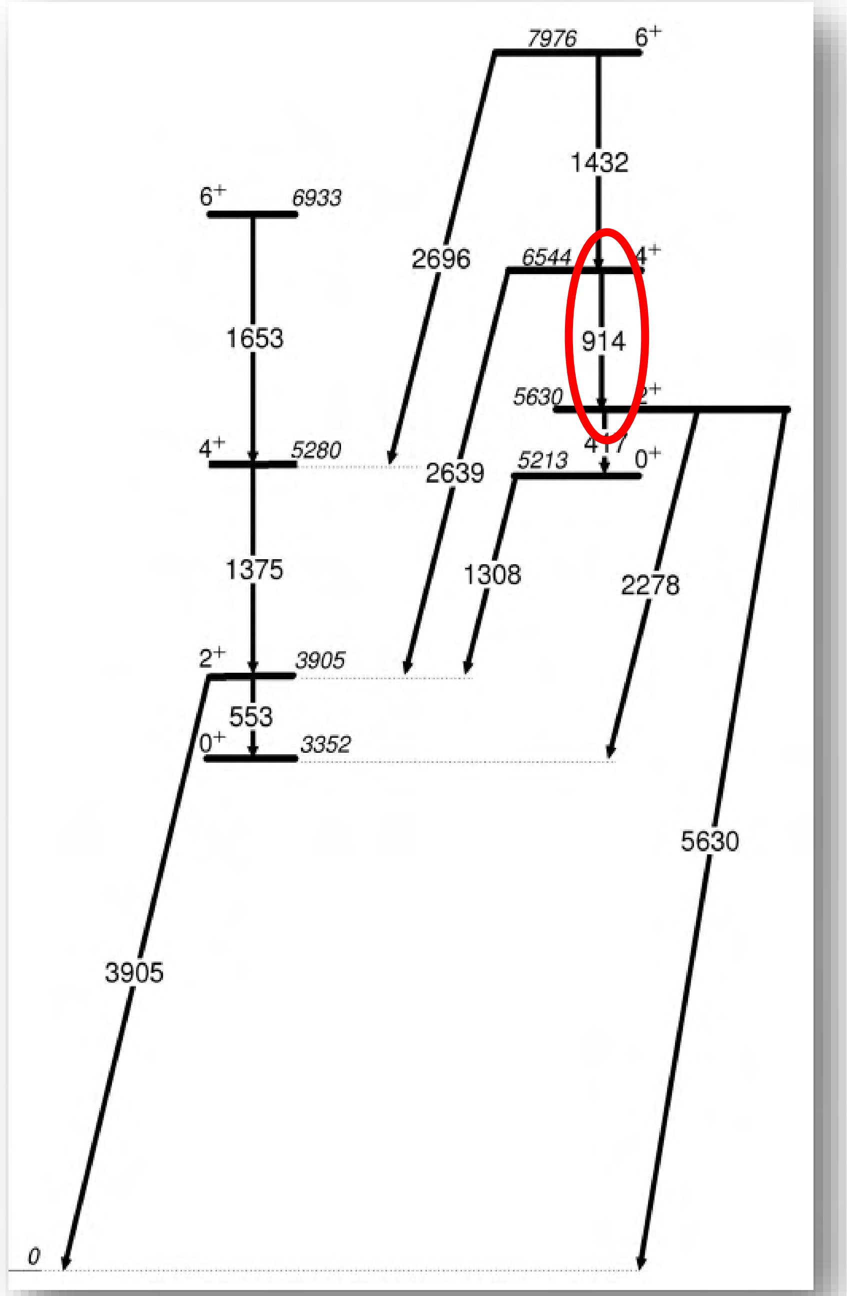
J. Srebrny and D. Cline, Int. J. Mod. Phys. E20, 422 (2011)

1. The sum rules derived from the rotational invariants allow measurement of the **expectation values** of rotational invariants built of **Q and δ**

2. It is possible to find the **statistical distribution of Q^2 and cos3δ** i.e. the first statistical moments related to the **softness** in both parameters

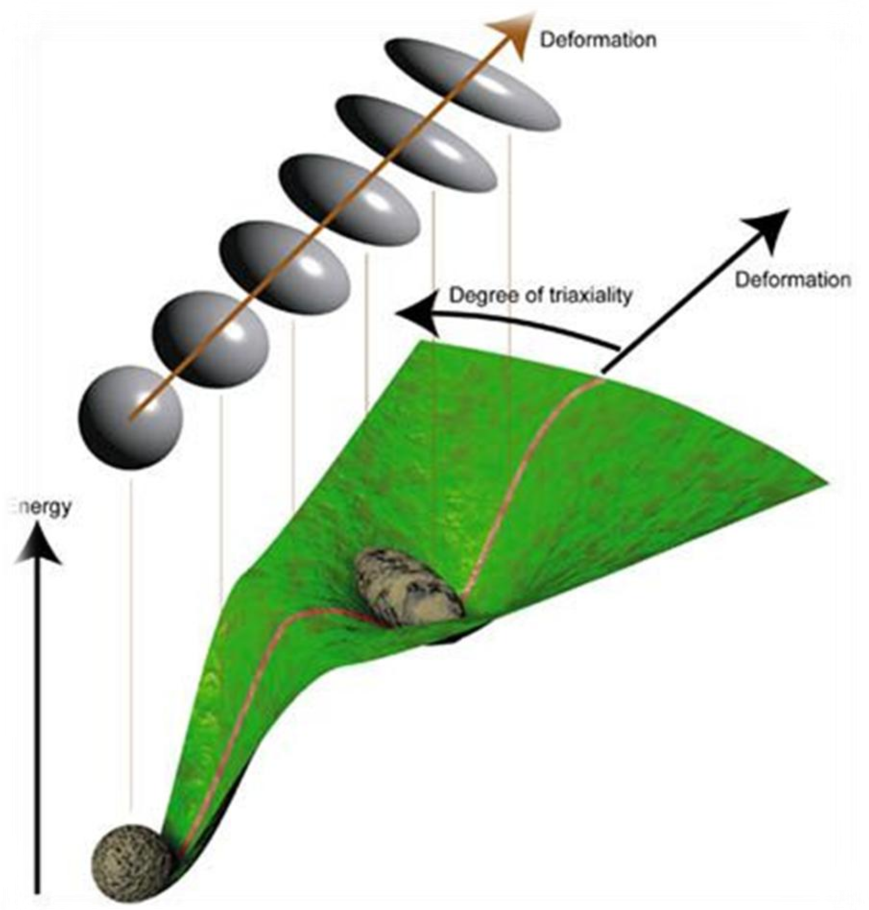
Deformation in ^{40}Ca region

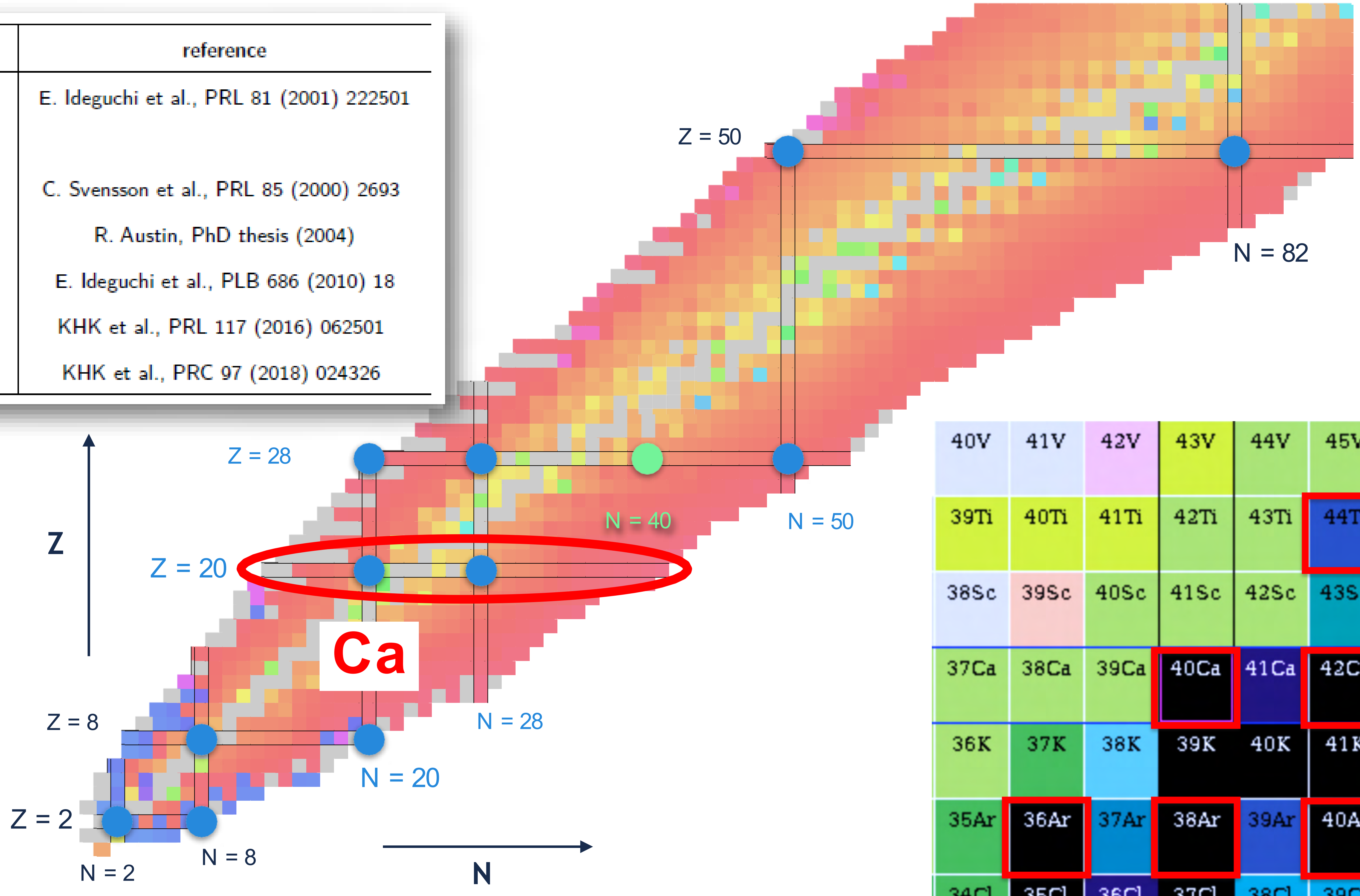


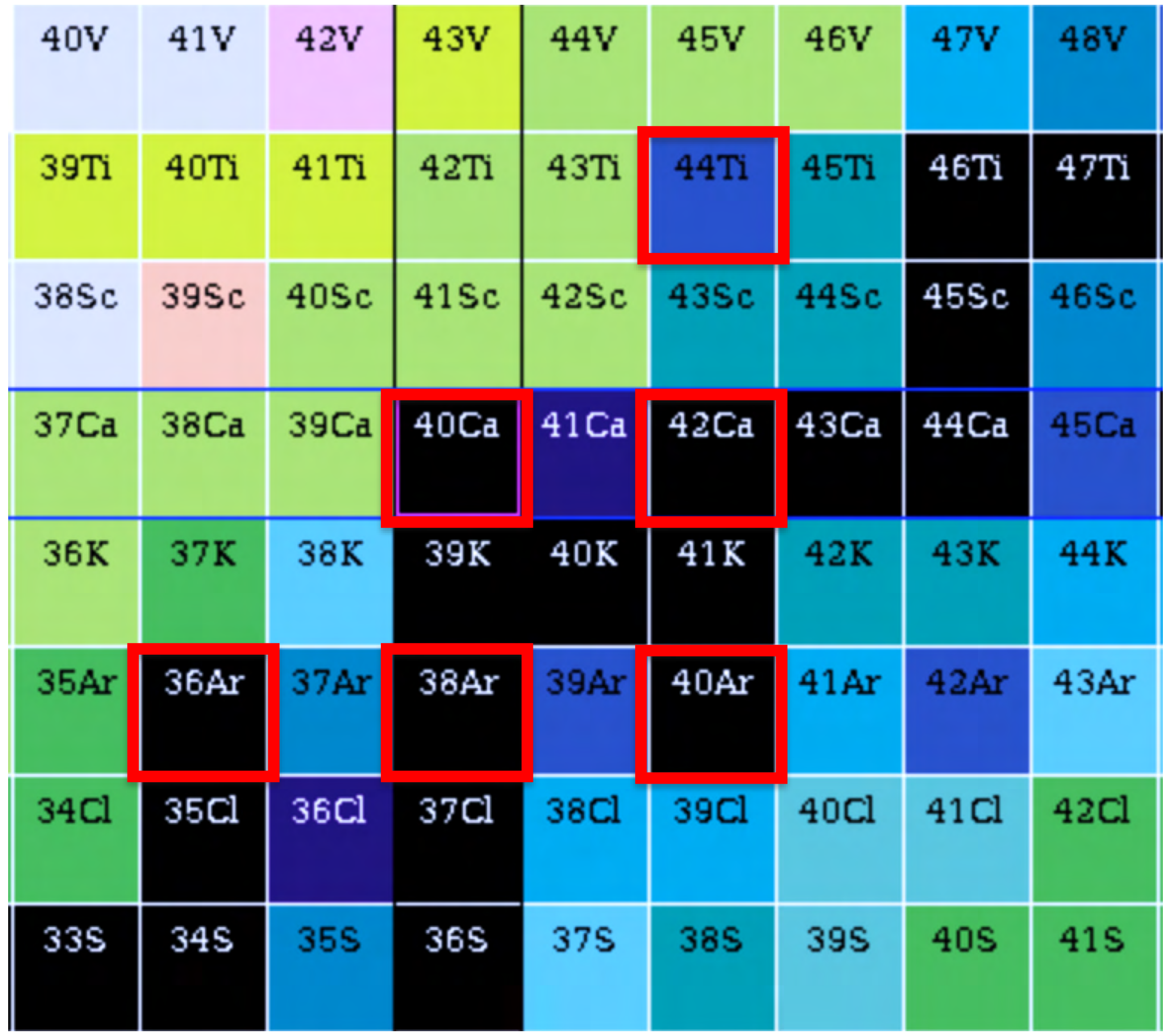


Deformation in ^{40}Ca region

isotope	0^+ energy	experimental β_2	configuration	reference
^{40}Ca	5.2 MeV	$0.59^{+0.11}_{-0.07}$	8p-8h (SD)	E. Ideguchi et al., PRL 81 (2001) 222501
	3.4 MeV	0.27 ± 0.05	4p-4h (ND)	
^{36}Ar	(4.3 MeV)	0.46 ± 0.03	4p-8h	C. Svensson et al., PRL 85 (2000) 2693
^{38}Ar	3.4 MeV	$0.42^{+0.11}_{-0.08}$	4p-6h	R. Austin, PhD thesis (2004)
^{40}Ar	2.1 MeV	$0.48^{+0.16}_{-0.10}\pm0.05$	4p-4h	E. Ideguchi et al., PLB 686 (2010) 18
^{42}Ca	1.8 MeV	0.43(4) (0_2^+)	6p-4h	KHK et al., PRL 117 (2016) 062501
		0.45(4) (2_2^+)		KHK et al., PRC 97 (2018) 024326







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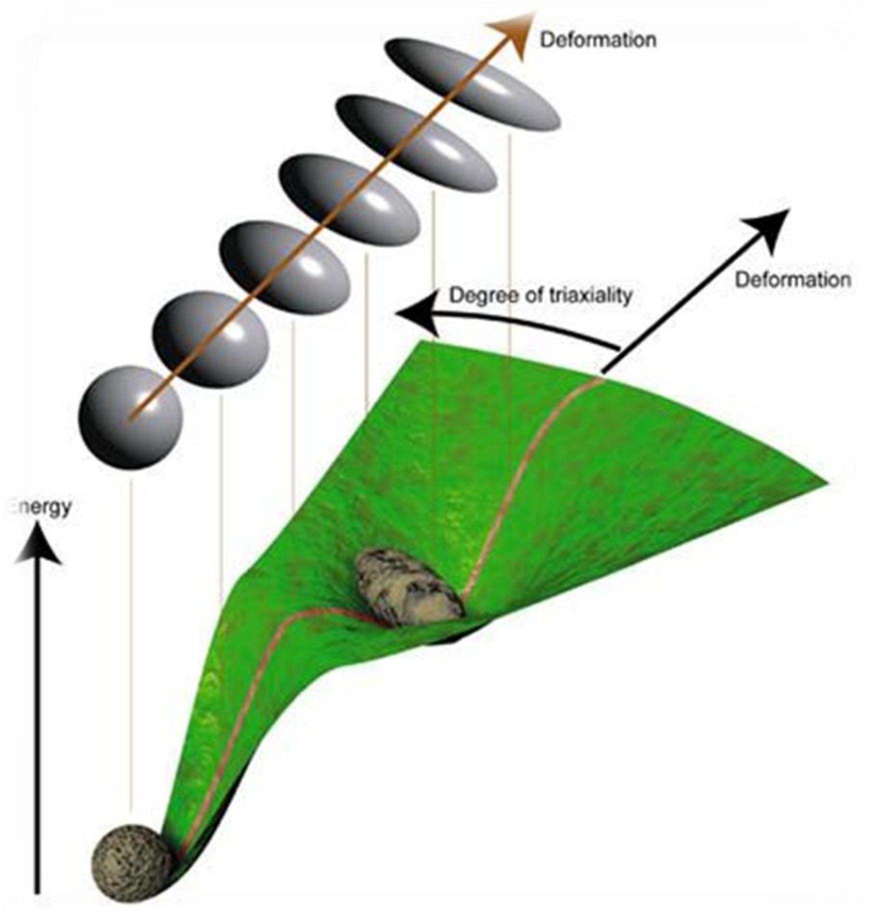
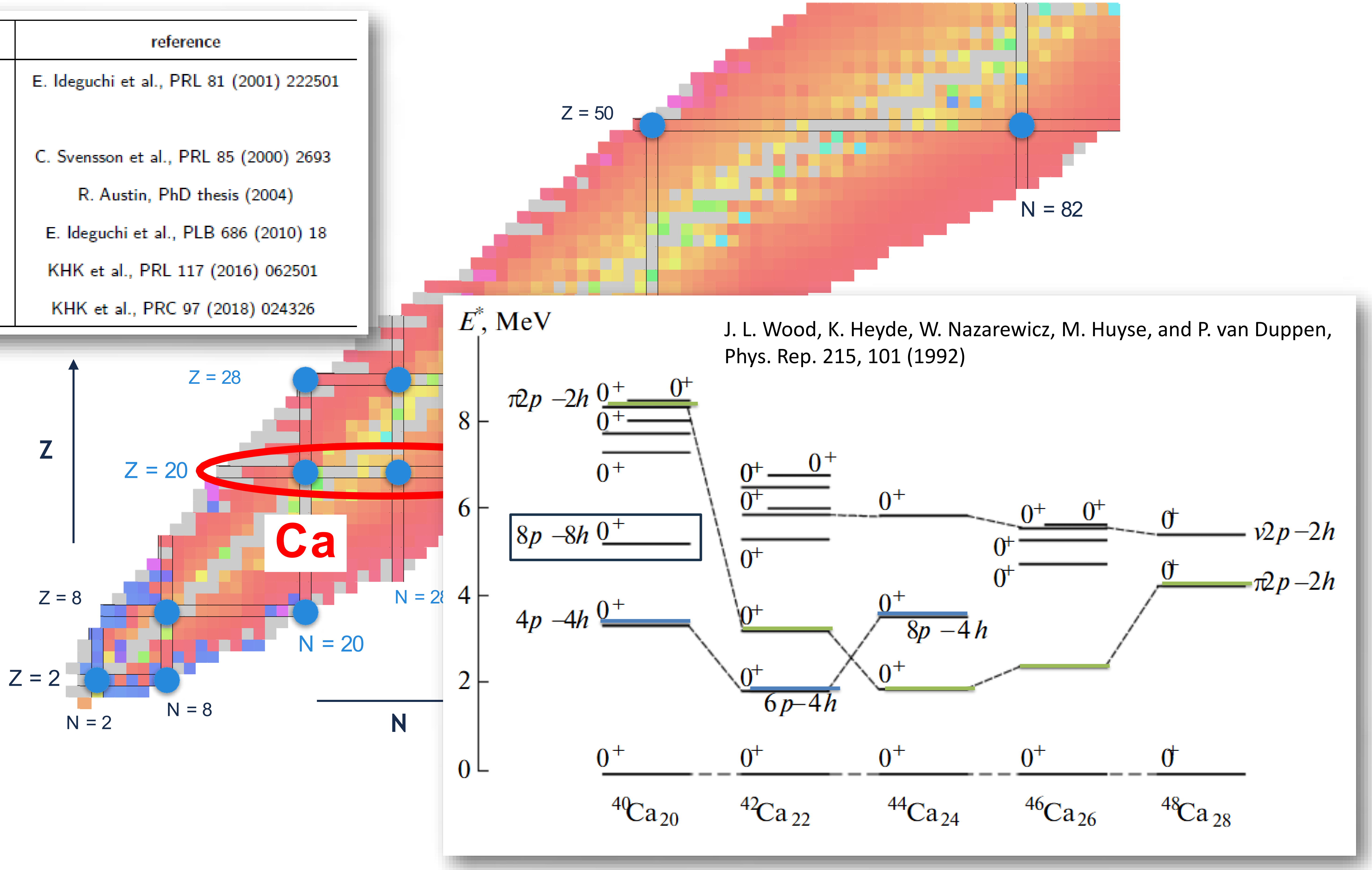
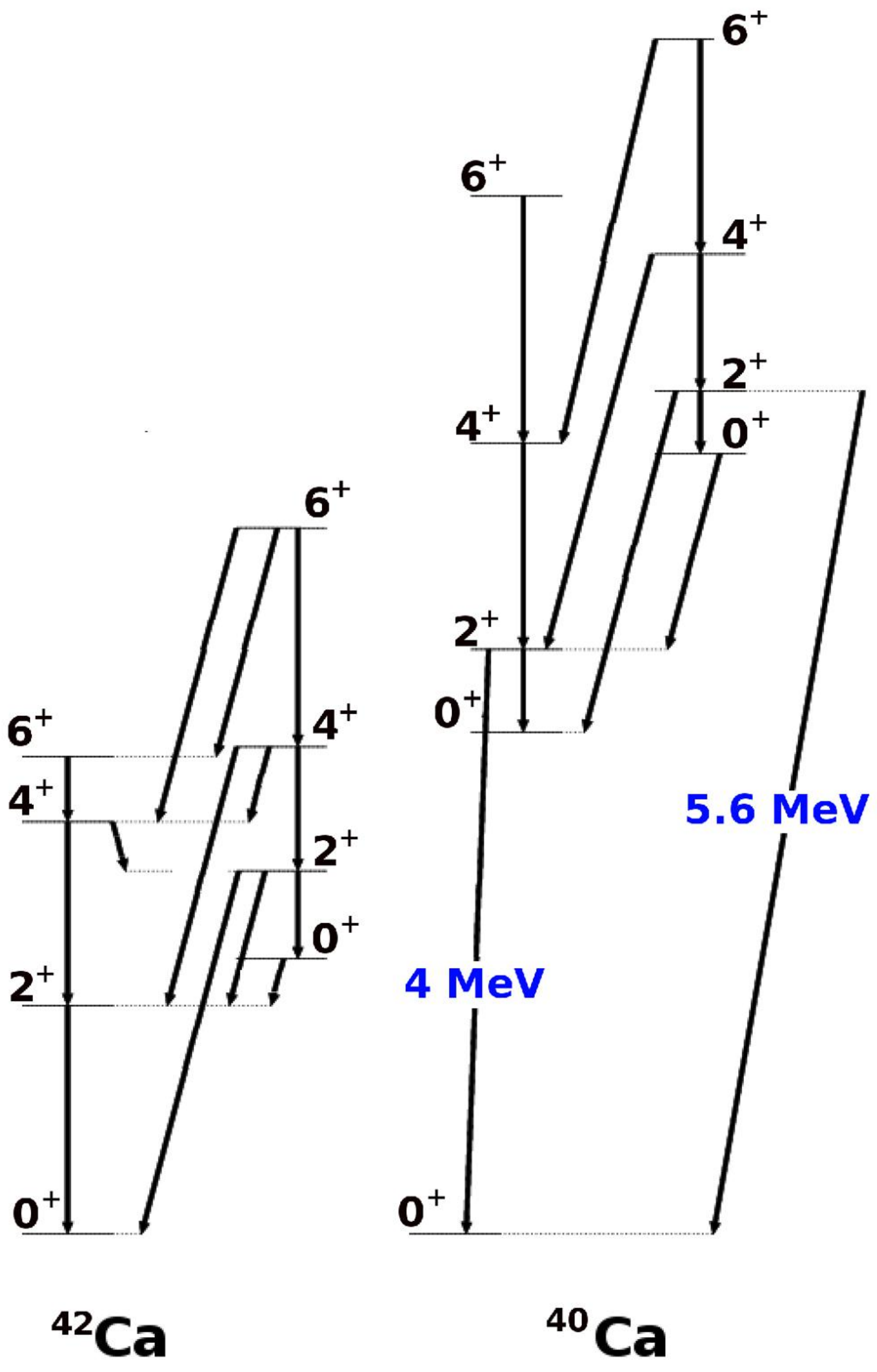


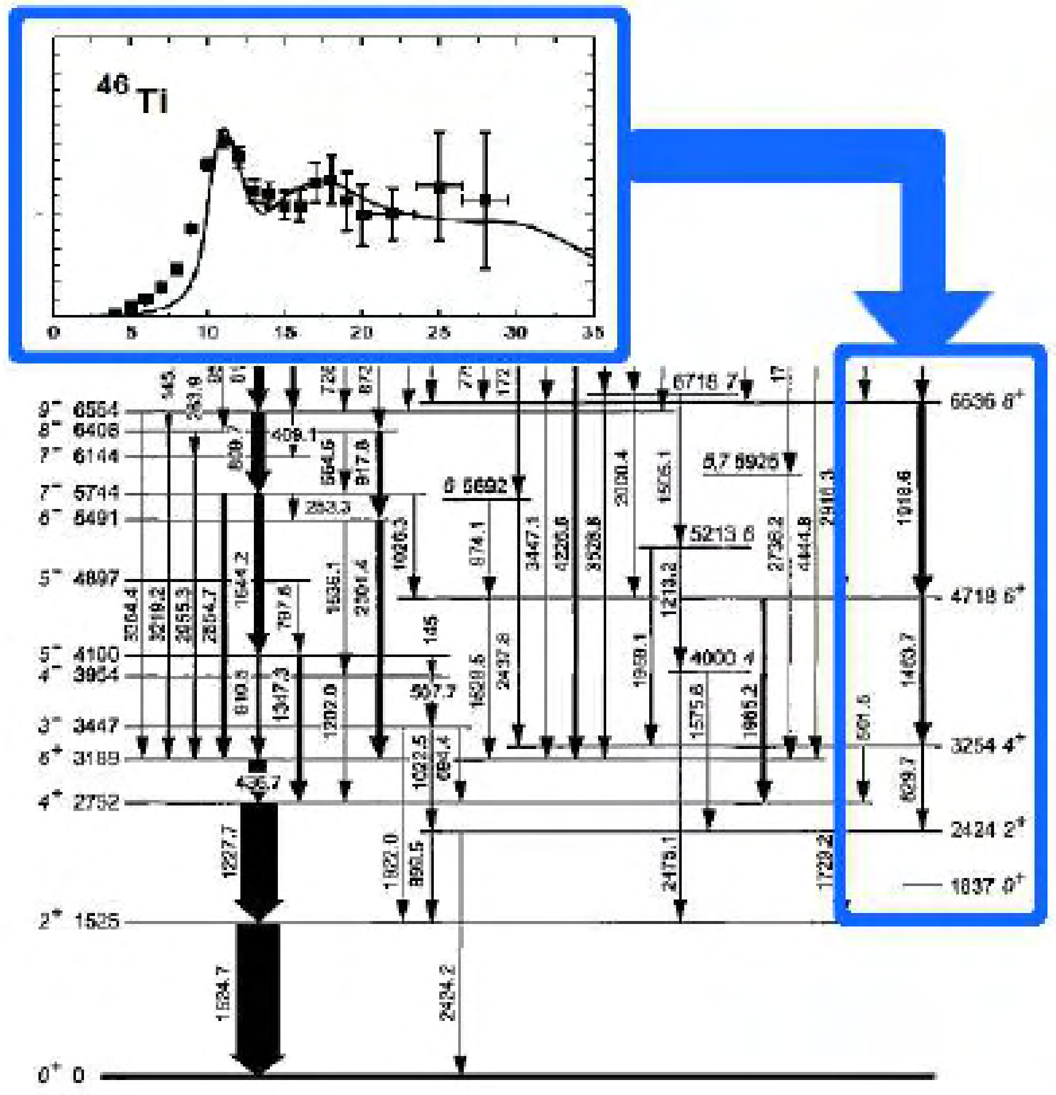


Case of ^{42}Ca (Z=20, N=22)



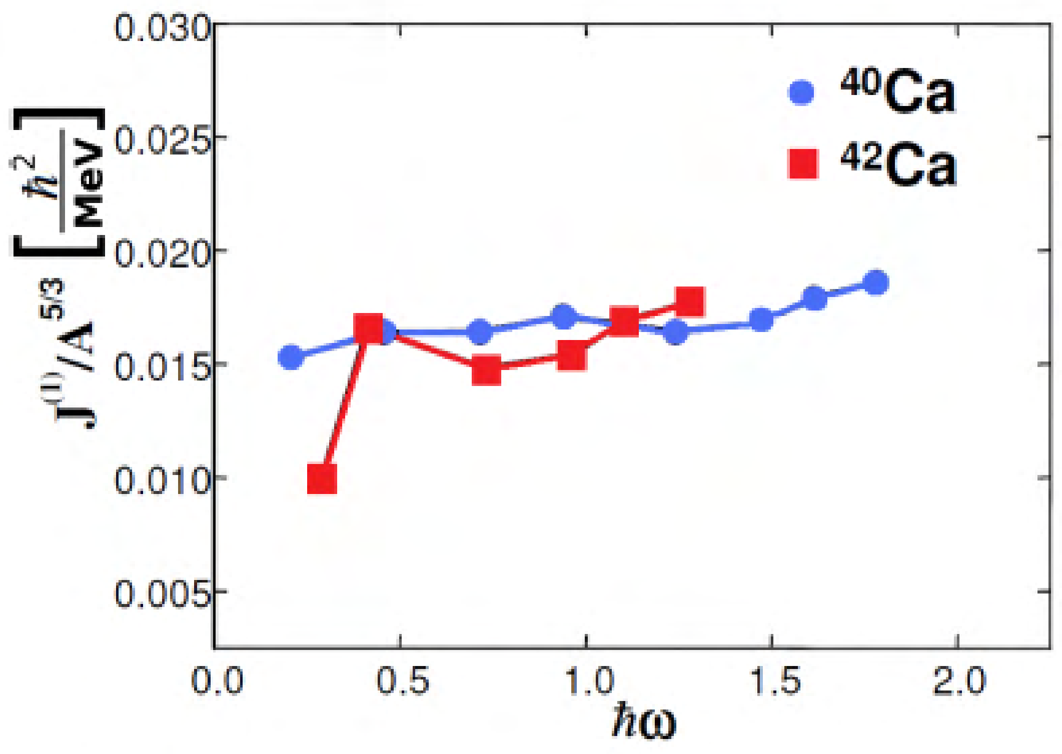
^{46}Ti Giant Dipole Resonance decay:

M. Kmiecik *et al.*, Acta Phys.Pol.B36, 1169(2005)



Moments of inertia of states in the side bands:

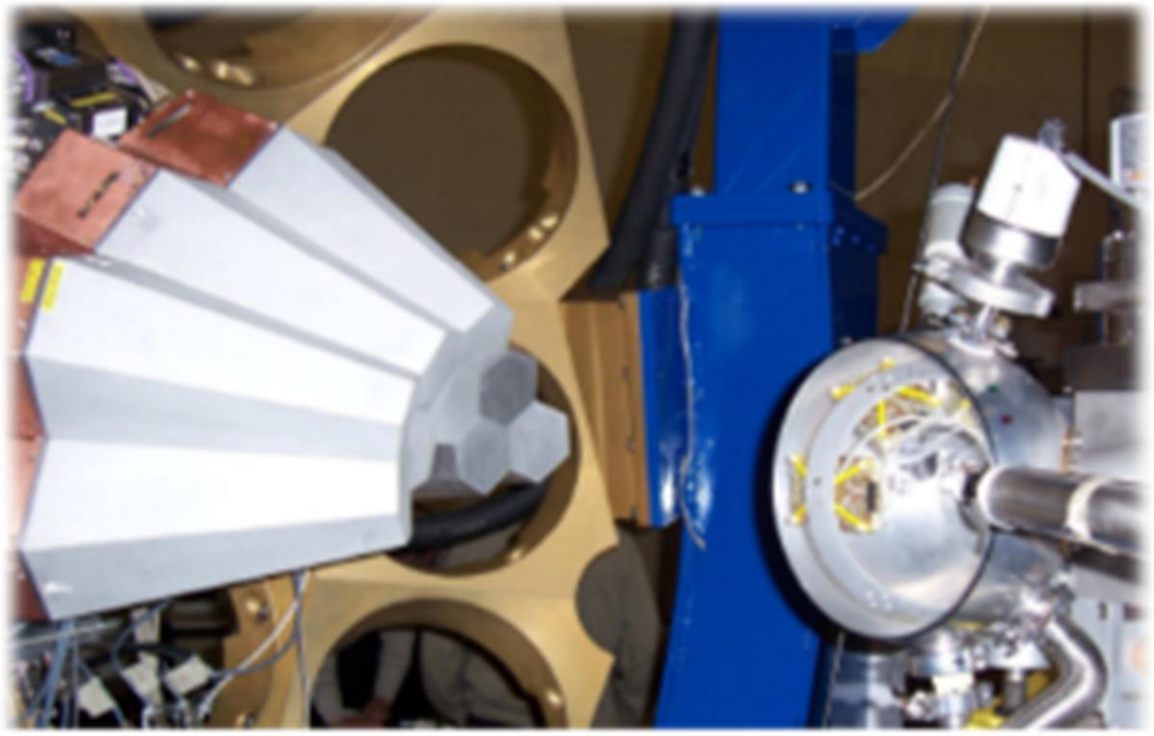
A.Maj *et al.* Key Topics in Nuclear Structure, page 417, (2005),
M.Lach *et al.* EPJ A 16, 3, 309-311 (2003)

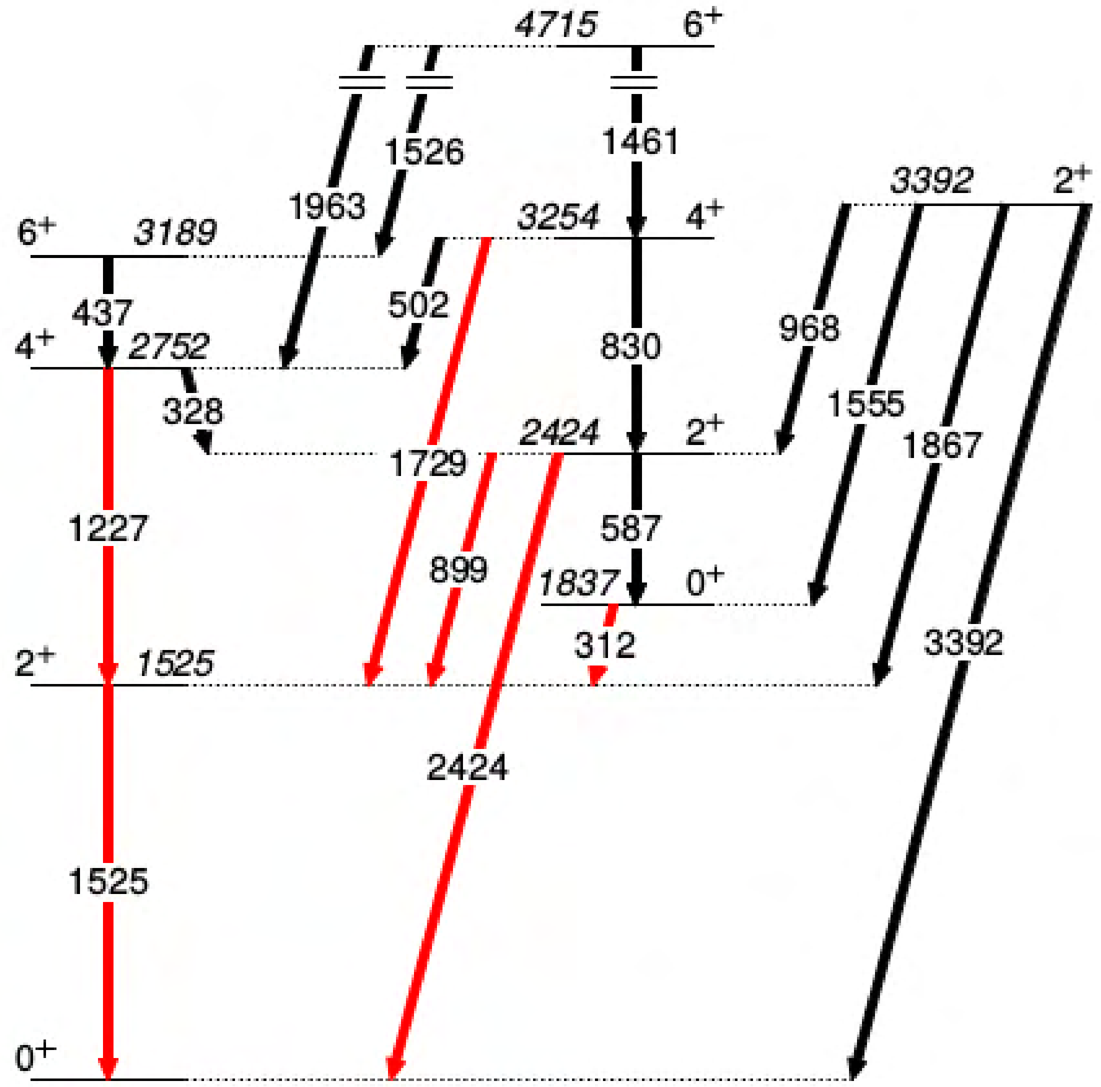


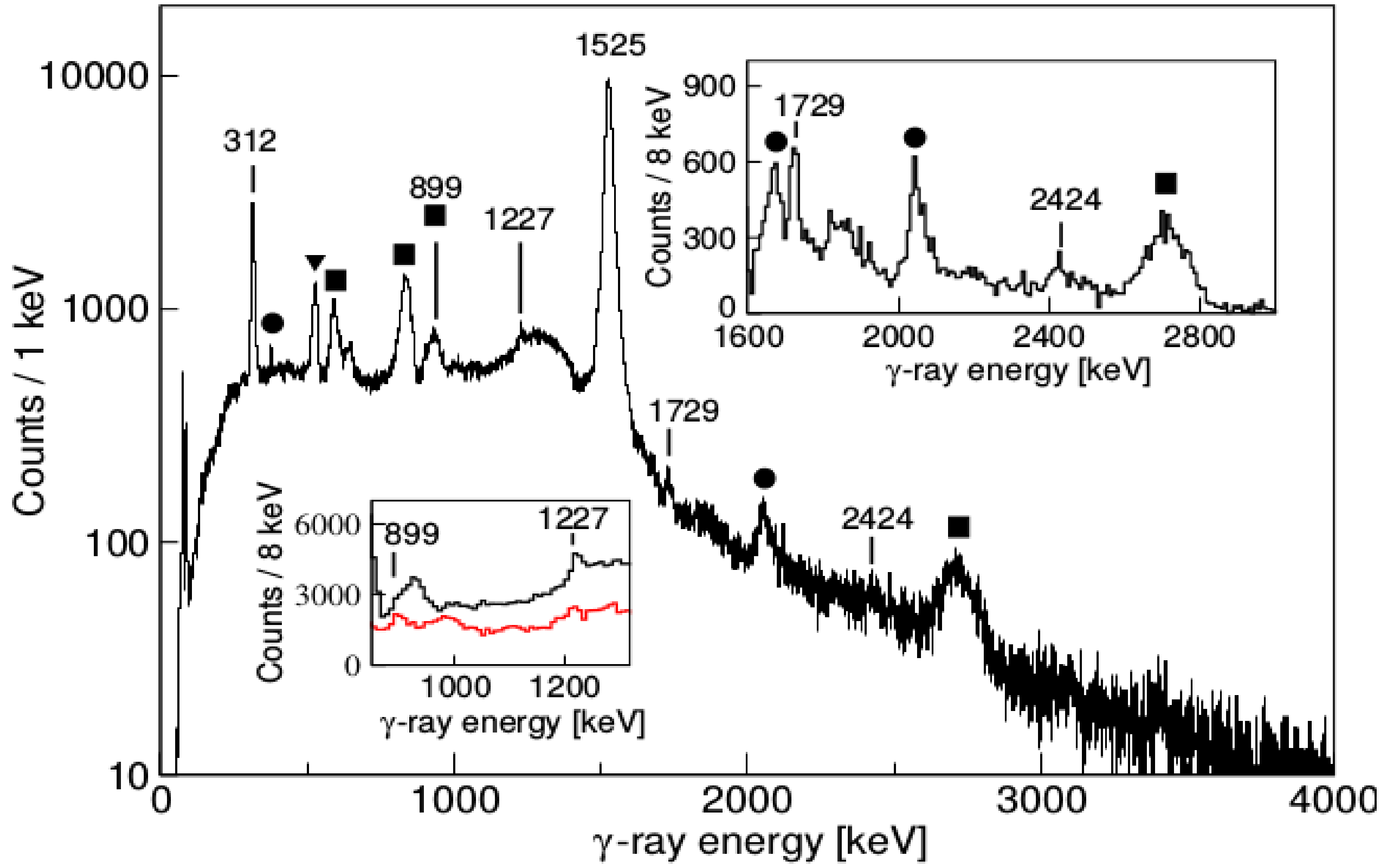
SD also in ^{42}Ca?

Coulomb excitation of ^{42}Ca

- INFN LNL
- Beam: ^{42}Ca, 170 MeV
- Targets:
  - ^{208}Pb, 1 mg/cm^2
  - ^{197}Au, 1 mg/cm^2
- AGATA: 3 triple clusters, 143.8 mm from the target
- DANTE: 3 Micro Channel Plate detectors, 100-144°



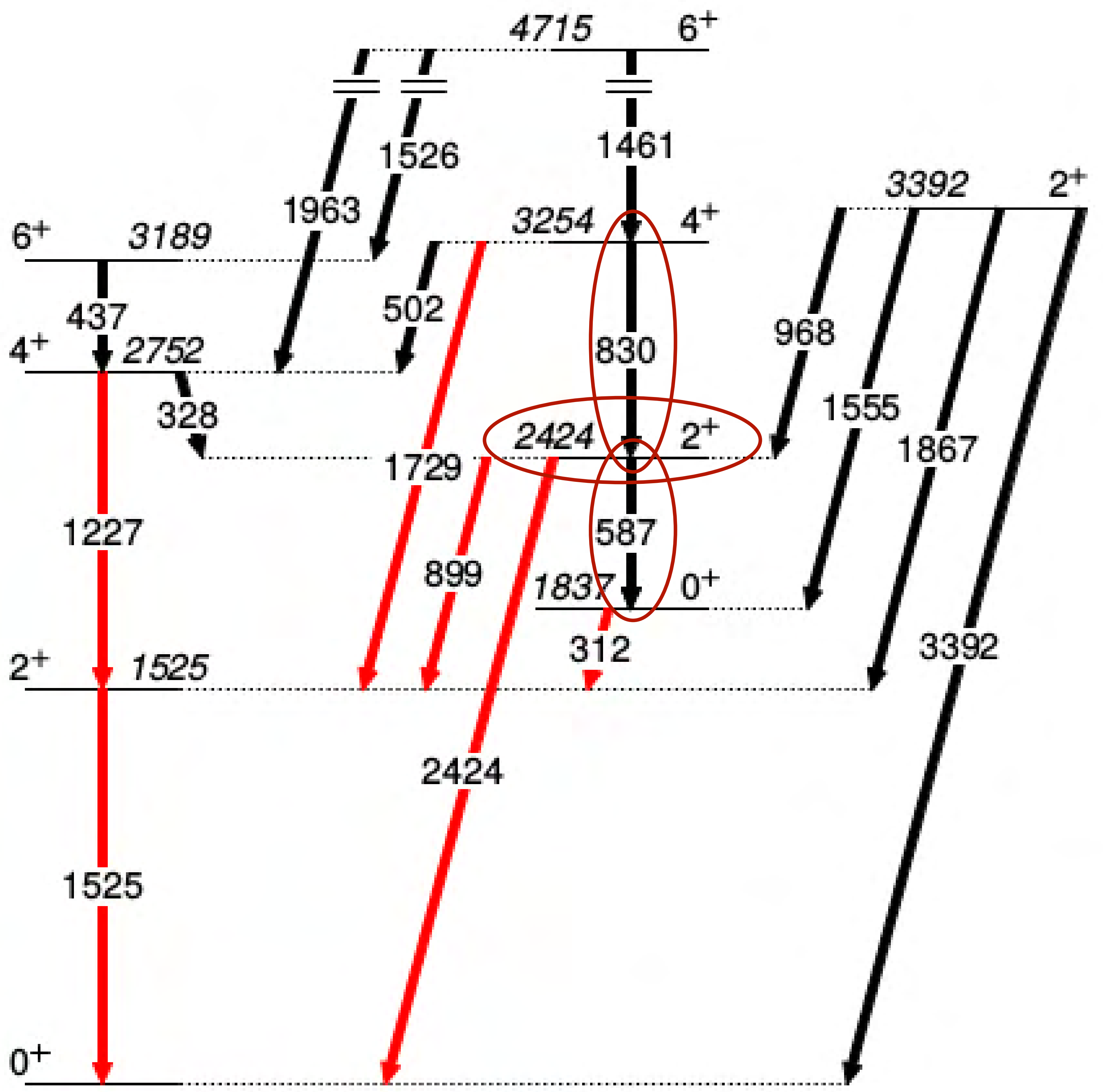




^{42}Ca - analysis

$I_i^+ \to I_f^+$	$\langle I_i \| E2 \| I_f \rangle$ [e fm^2] Present	$B(E2\downarrow; I_i^+ \to I_f^+)$ [W.u.] Present	$B(E2\downarrow; I_i^+ \to I_f^+)$ [W.u.] Previous
$2_1^+ \to 0_1^+$	$20.5^{+0.6}_{-0.6}$	$9.7^{+0.6}_{-0.6}$	9.3 ± 1 [36] 11 ± 2 [28] 9 ± 3 [27] 8.5 ± 1.9 [45]
$4_1^+ \to 2_1^+$	$24.3^{+1.2}_{-1.2}$	$7.6^{+0.7}_{-0.7}$	50 ± 15 [28] 11 ± 3 [27] 10^{+10}_{-8} [45]
$6_1^+ \to 4_1^+$	$9.3^{+0.2}_{-0.2}$	$0.77^{+0.03}_{-0.03}$	0.7 ± 0.3 [27]
$0_2^+ \to 2_1^+$	$22.2^{+1.1}_{-1.1}$	57^{+6}_{-6}	64 ± 4 [27] 100 ± 6 [28] 55 ± 1 [42] 64 ± 4 [45]
$2_2^+ \to 0_1^+$	$-6.4^{+0.3}_{-0.3}$	$1.0^{+0.1}_{-0.1}$	2.2 ± 0.6 [28] 1.5 ± 0.5 [27] 1.2 ± 0.3 [45]
$2_2^+ \to 2_1^+$	$-23.7^{+2.3}_{-2.7}$	$12.9^{+2.5}_{-2.5}$	17 ± 11 [28] 19^{+22}_{-14} [27] 14^{+35}_{-9} [45]
$4_2^+ \to 2_1^+$	42^{+3}_{-4}	23^{+3}_{-4}	30 ± 11 [28] 16 ± 5 [27] 12^{+7}_{-4} [45]
$2_2^+ \to 0_2^+$	26^{+5}_{-3}	15^{+6}_{-4}	< 61 [27] < 46 [45]
$4_2^+ \to 2_2^+$	46^{+3}_{-6}	27^{+4}_{-6}	60 ± 30 [27] 60 ± 20 [28] 40^{+40}_{-30} [45]

	$\langle I_i \| E2 \| I_f \rangle$ [e fm^2]	Q_{sp} [e fm^2]	
$2_1^+ \to 2_1^+$	-16^{+9}_{-3}	-12^{+7}_{-2}	-19 ± 8 [36]
$2_2^+ \to 2_2^+$	-55^{+15}_{-15}	-42^{+12}_{-12}	



KHK et al., PRL 117, 062501 (2016)
KHK et al., PRC 97, 024326 (2018)

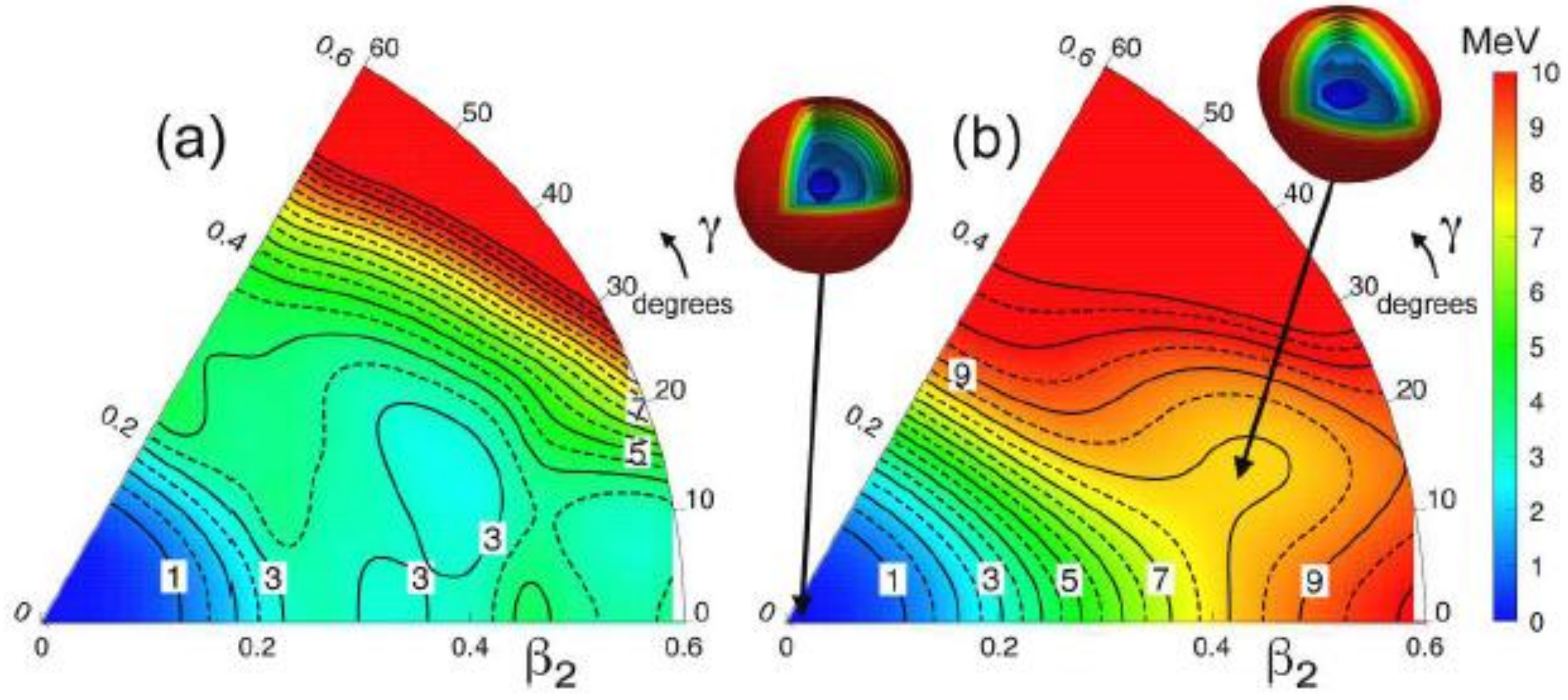
^{42}Ca - theory

Large Scale Shell Model

- F.Nowacki, H.Naïdja, B.Bounthong
  Universitet de Strasbourg, France
- ANTOINE code
- 6 particle-hole excitations from $s_{1/2}$ and $d_{3/2}$ orbitals to pf orbitals
- Effective charges: $1.5e$ (protons) and $0.5e$ (neutrons)
- Same method as in ^{40}Ca:
  E.Caurier, J.Menendez, F.Nowacki and A.Poves, Phys. Rev. C 75, 054317 (2007)

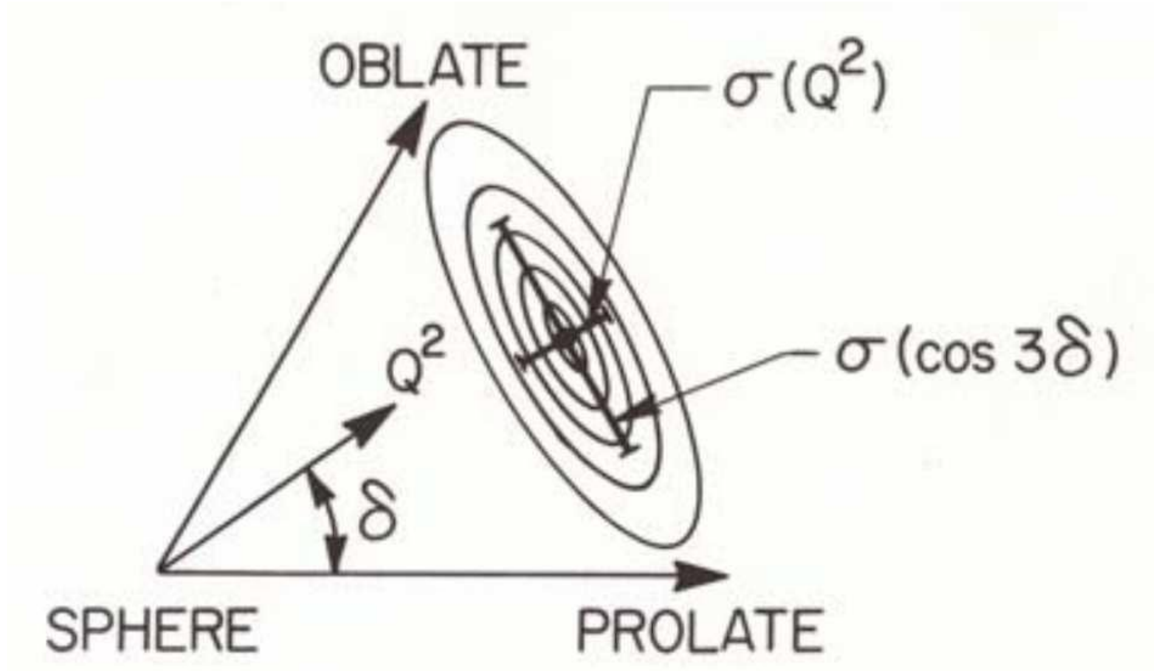
Beyond Mean Field

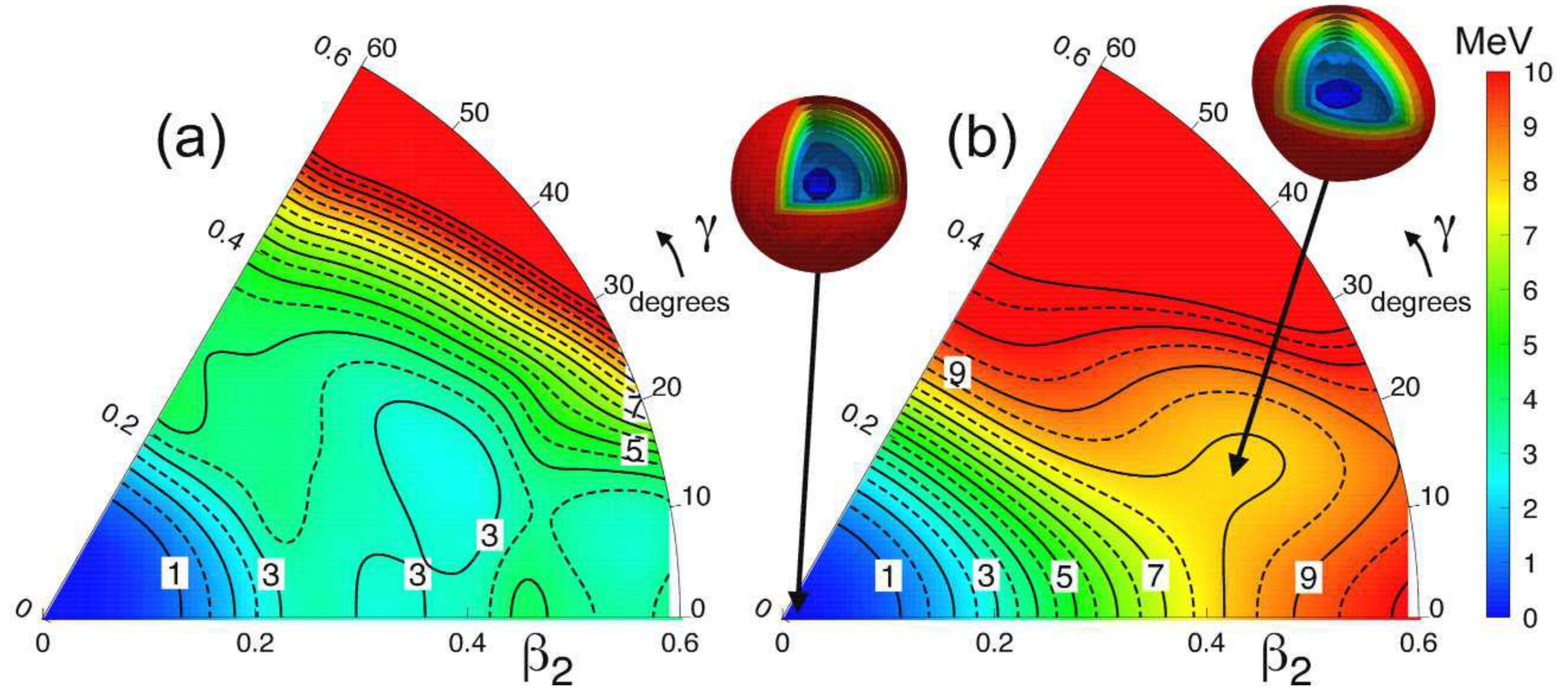
- T. R. Rodríguez
  Universidad Autónoma de Madrid, Spain
- RVAMPIRE code:
  T.R.Rodríguez and J.L.Egido, Phys. Rev. C 81, 064323 (2010)
- HFB, Gogny D1S interaction to define the energy density functional
- Particle number and angular momentum symmetry restoration
- Quadrupole (axial and non-axial) shape mixing within generator coordinate method



Both approaches predict:
0_1^+ – SPHERICAL
0_2^+ – TRIAXIAL/PROLATE

Shape coexistence in ^{42}Ca





	EXP		SM		BMF	
state	$\langle Q^2\rangle$	$\sigma(Q^2)$	$\langle Q^2\rangle$	$\sigma(Q^2)$	$\langle Q^2\rangle$	$\sigma(Q^2)$
0_1^+	480 (20)	350 (30)	240	470	100	250
2_1^+	890 (100)		250	490	100	310
0_2^+	1310 (250)	350 (30)	1200	500	1910	520
2_2^+	1440 (250)		1130	500	1970	310

state	$\langle\cos(3\delta)\rangle_{exp}$	$\langle\cos(3\delta)\rangle_{SM}$	$\langle\cos(3\delta)\rangle_{BMF}$
0_1^+	0.06 (10)	0.34	0.34
0_2^+	0.79 (13)	0.67	0.49

Ground state deformation:
spherical, with the large fluctuations (DYNAMIC):

<Q^2> + σ(Q^2) and <cos(3d)>

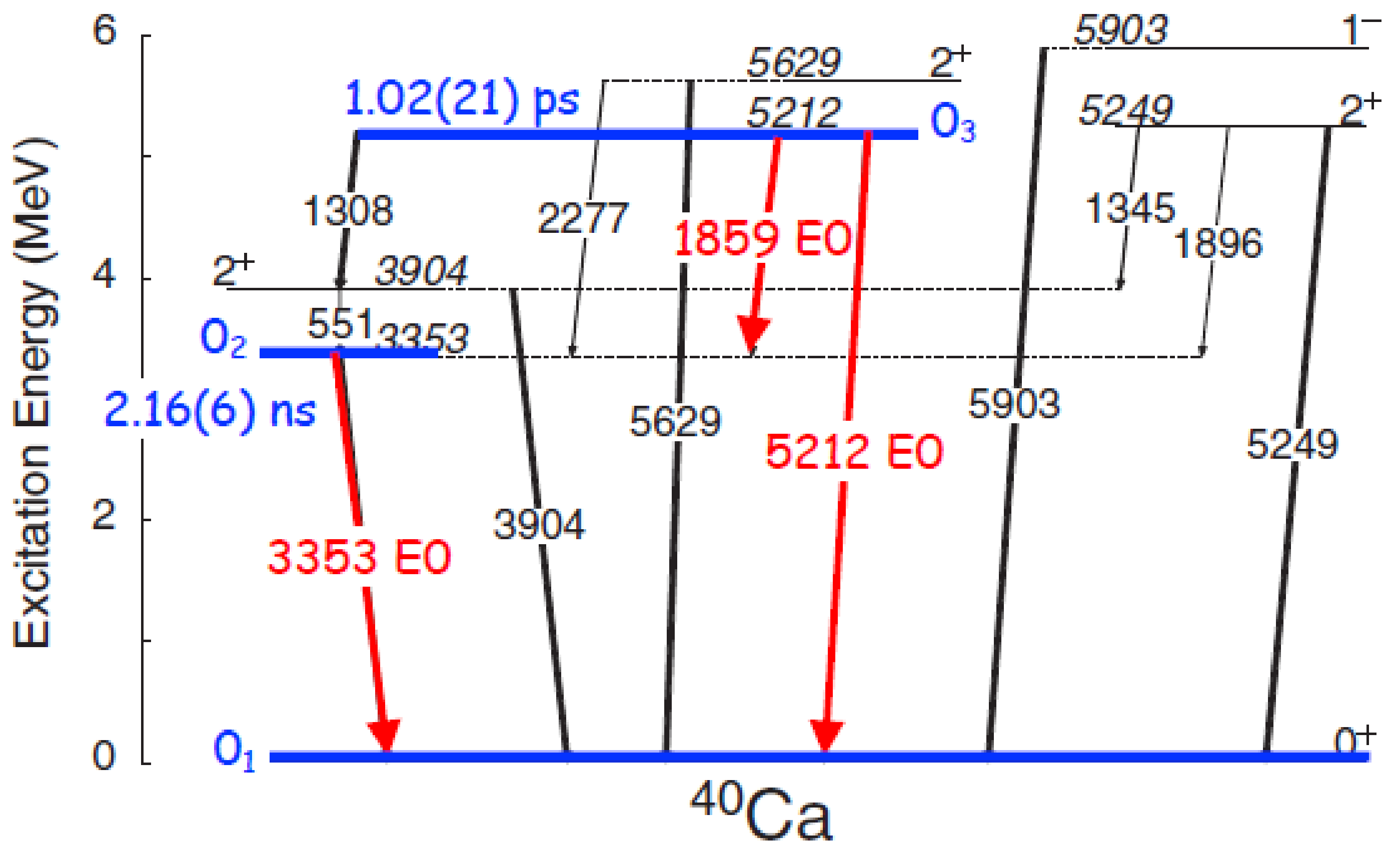
$$0_1^+ \ \bar{\beta}=0.26(2) \text{ and } \bar{\gamma}=29(2)^\circ$$

Excited 0$^+$:
Triaxial prolate – superdeformed (STATIC):

$$0_2^+ \ \bar{\beta}=0.43(4) \text{ and } \bar{\gamma}=13(^5_6)^\circ$$

Intriguing case of ^{40}Ca

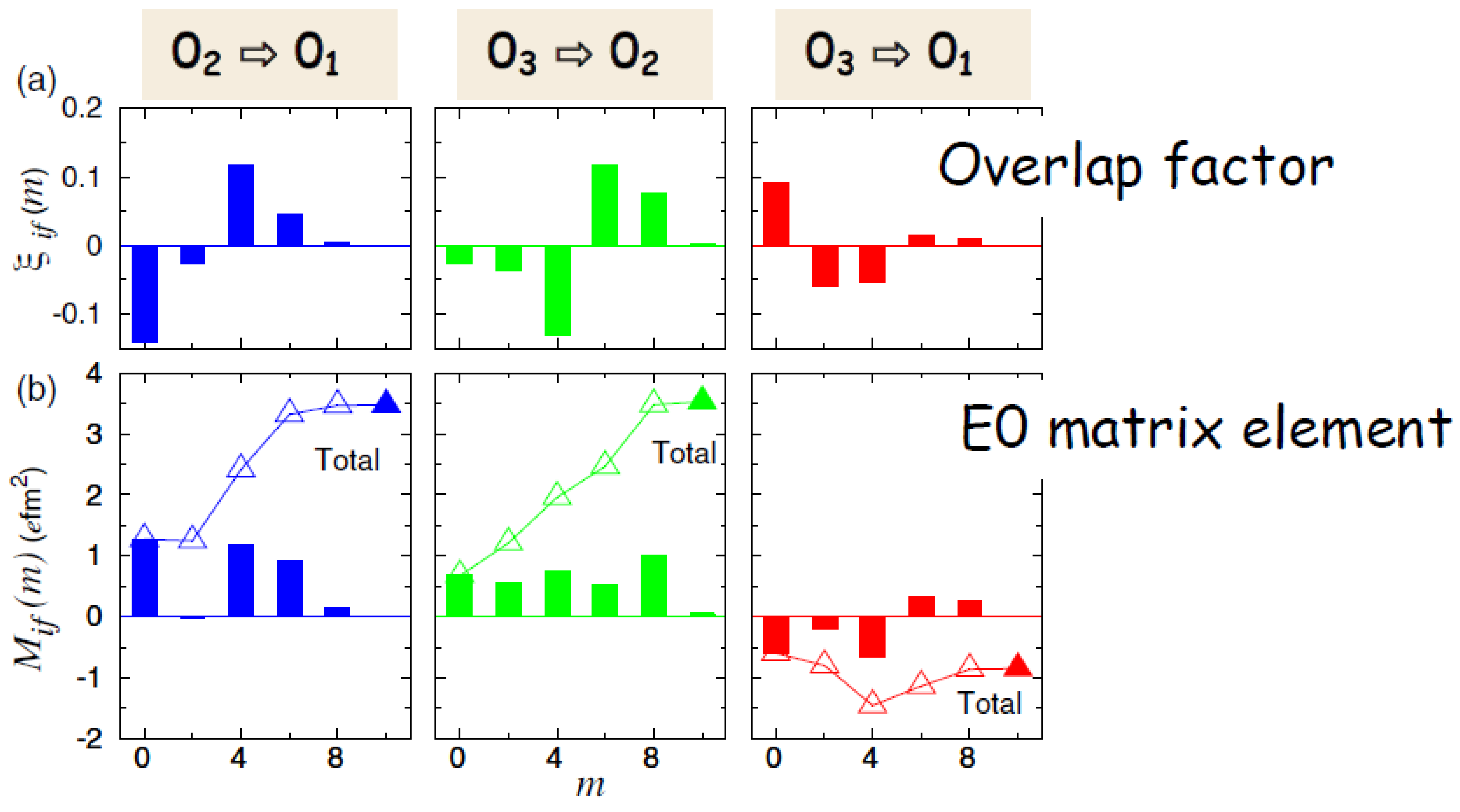
Ideguchi et al., Phys. Rev. Lett. 128 (2022) 252501

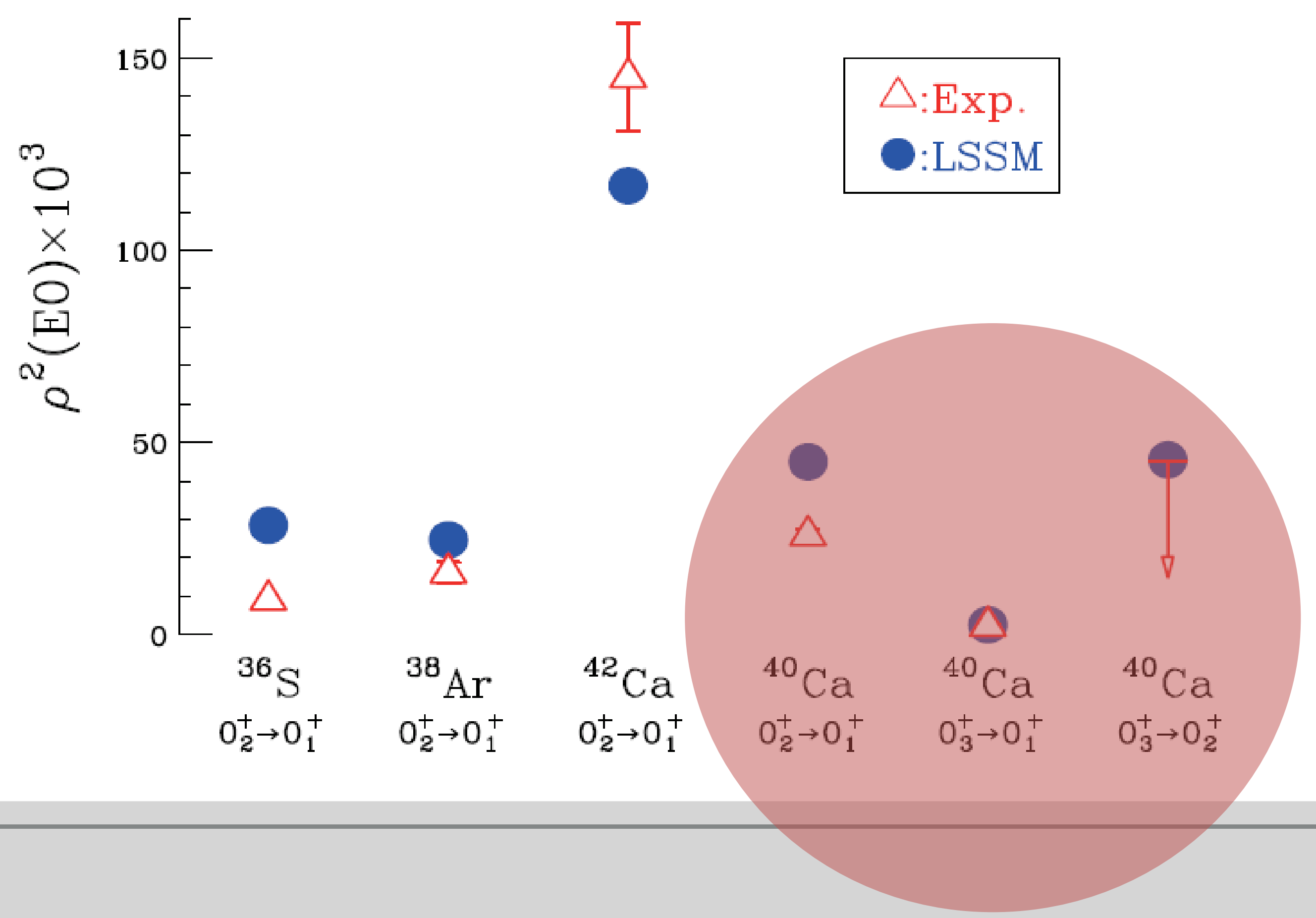


$10^3\rho^2(E0, 0_2 \to 0_1)$ = 25.9(16
$10^3\rho^2(E0, 0_3 \to 0_1)$ = 2.3(5)
$10^3\rho^2(E0, 0_3 \to 0_2)$ < 45

Smallest value in A<60 nuclei!

N. Shimizu (CNS, UTK) and Y. Utsuno (JAEA)





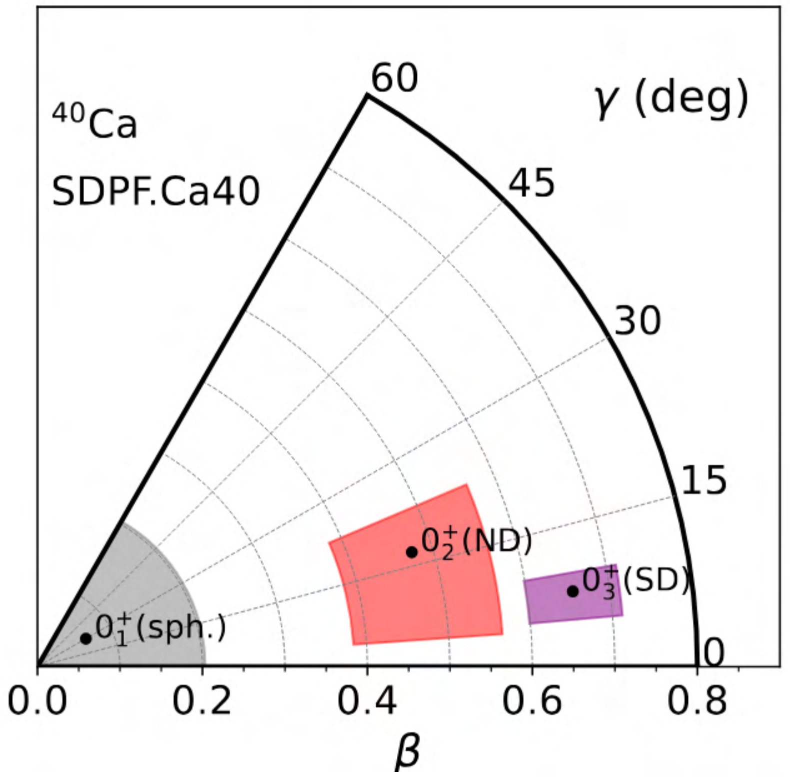
- Significant mixing between 0^+ states
- The unusually small $\rho^2(E0; 0^+_3 \to 0^+_1)$ value is due to destructive interference in the mixing of shape-coexisting structures, which are based on several different multiparticle-multihole excitations.
- **Is 0^+ GS really spherical?**
- What is the deformation of the 0^+_3 state?

Courtesy of T. Kibedi (Australian National Uni)

^{40}Ca – LSSM theory

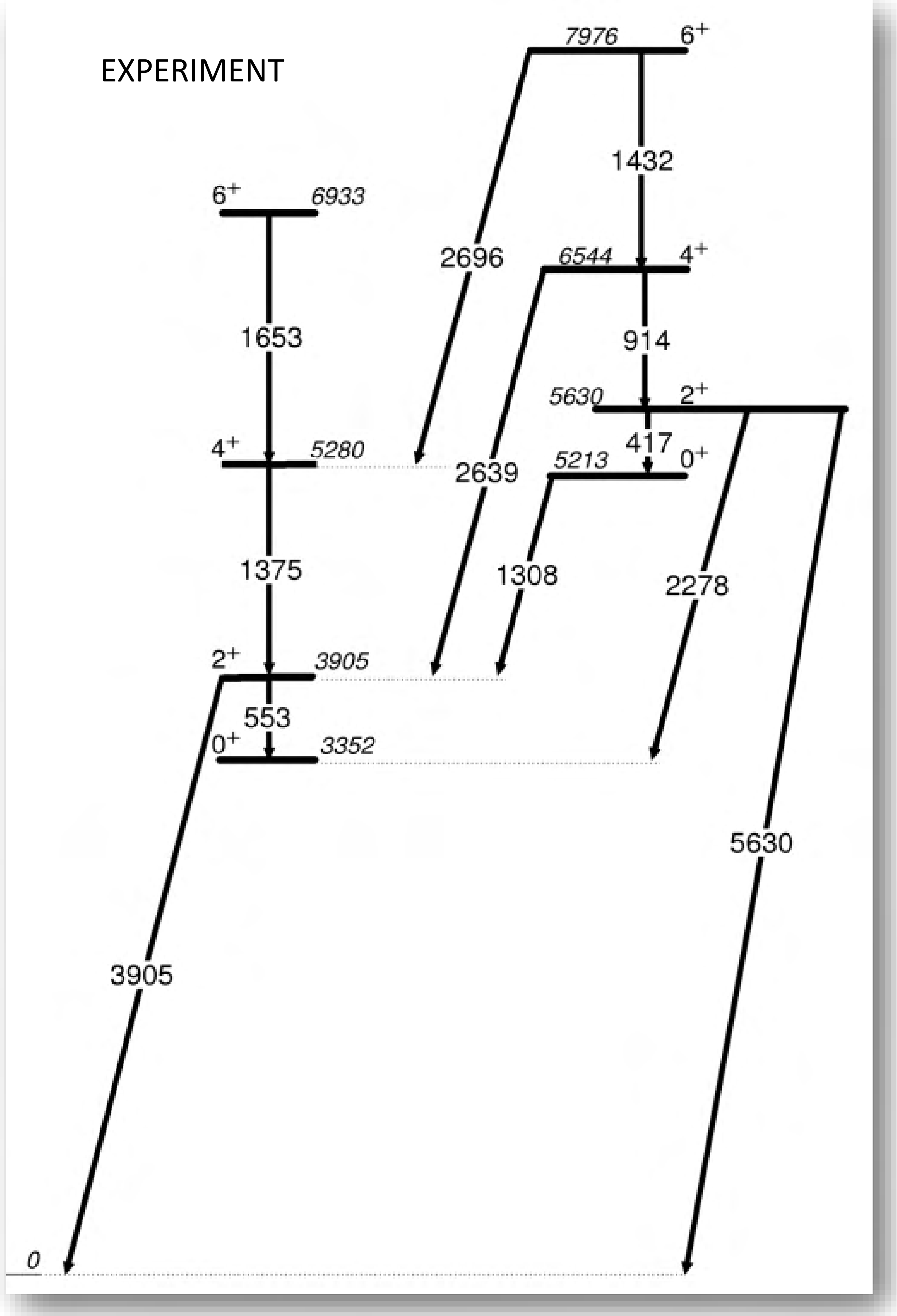
Courtesy:
Dorian Frycz and Javier Menéndez

$e_n = 0.5e$, $e_p = 1.5e$
r2pf valence space
sdpf orbitals with closed $0d_{5/2}$
50 iterations of the Lanczos method for each J^π

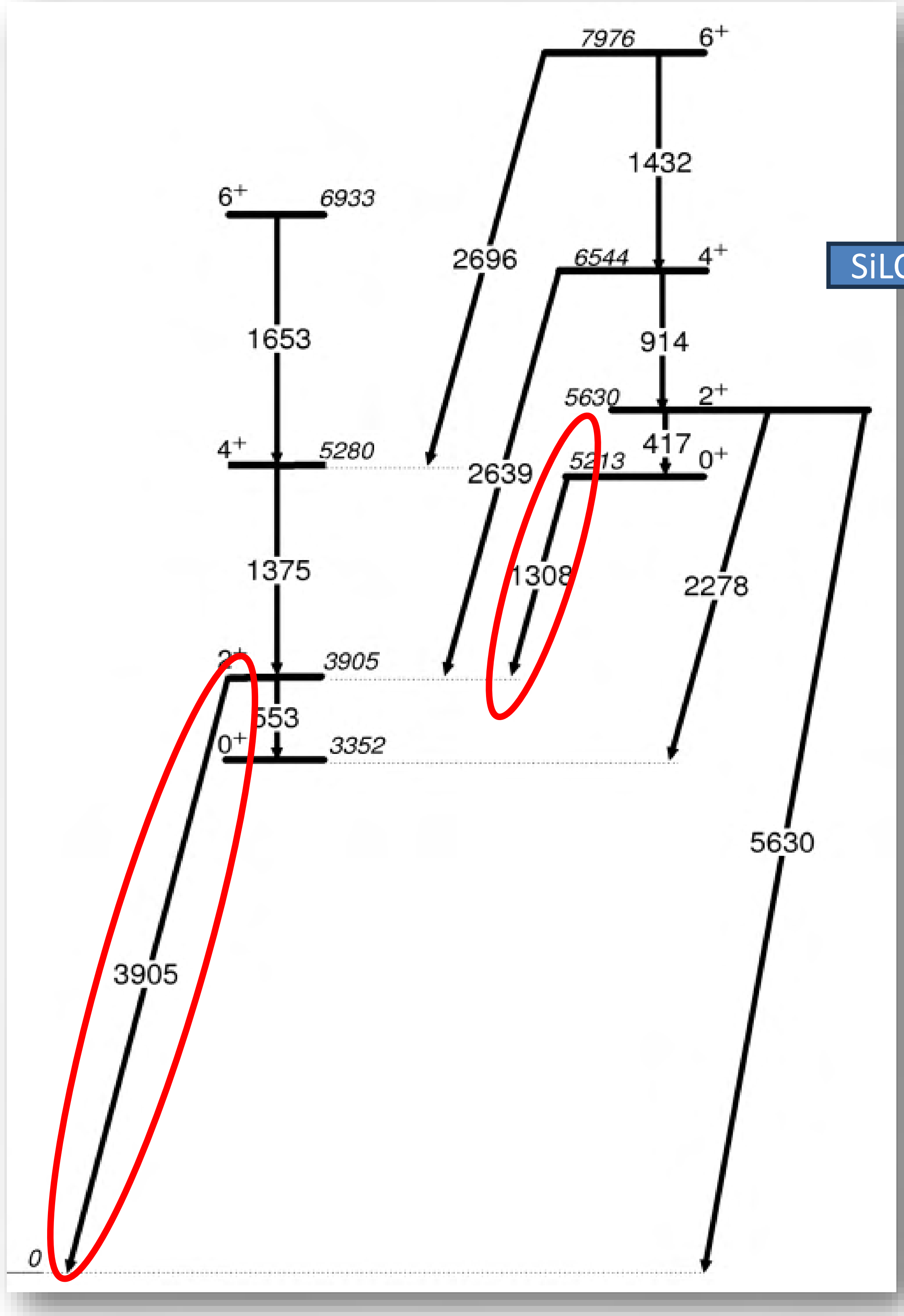


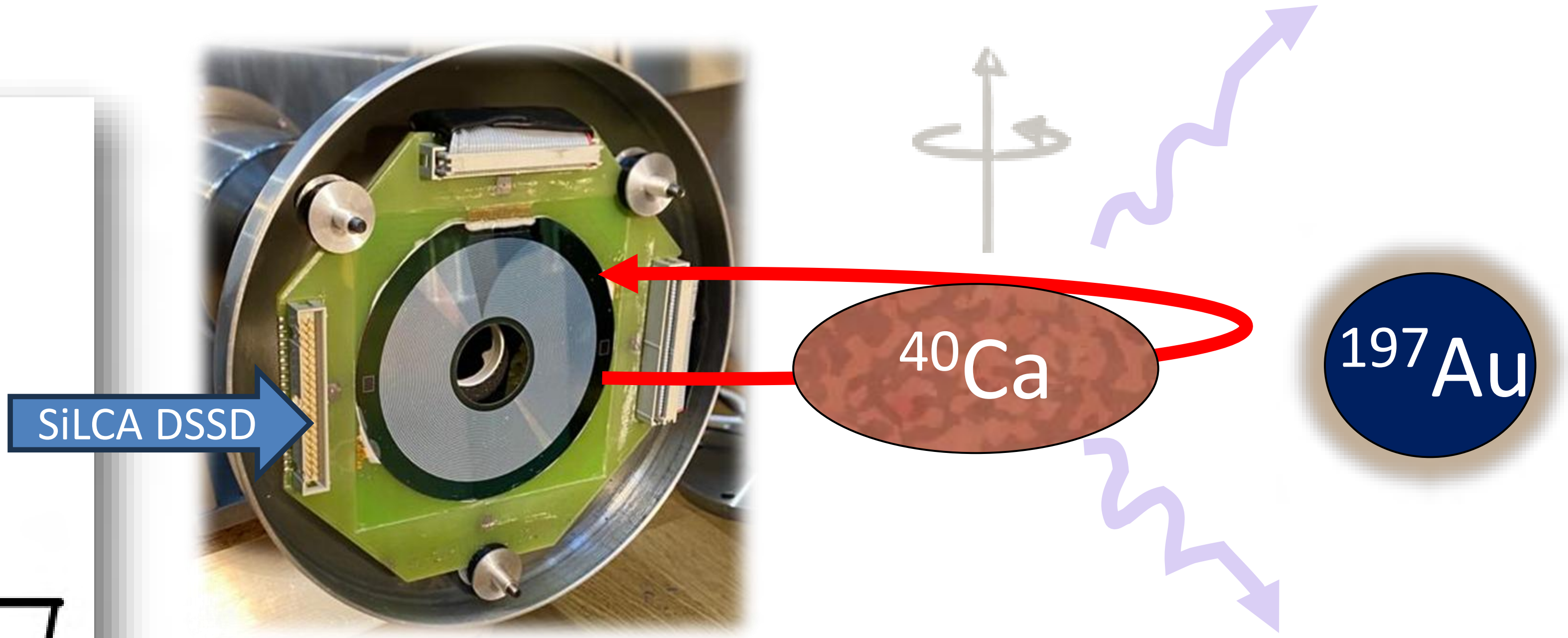
	0p-0h	2p-2h	4p-4h	6p-6h	8p-8h	E_{theo} (MeV)	E_{exp} (MeV)
0_1^+	65	29	5	-	-	0	0
0_2^+	1	1	64	25	9	3.49	3.35
0_3^+	-	-	9	4	87	4.80	5.21

Shape	J^π_σ	Energy (MeV)	$\beta \pm \Delta\beta$	γ (°)	γ_{min}-γ_{max} (°)
Spherical	0_1^+	0.00	0.07±0.14	-	(0-60)
Normal deformed	0_2^+	3.49	0.47±0.09	17	(4-23)
	2_1^+	4.23	0.47±0.09	8	(0-15)
	4_1^+	5.40	0.45±0.05	10	(7-12)
Superdeformed	0_3^+	4.80	0.66±0.06	8	(5-10)
	2_2^+	5.26	0.64±0.07	4	(0-9)
	4_2^+	6.28	0.64±0.02	6	(0-9)



Coulomb excitation of ^{40}Ca – IJC Lab, Orsay





PARIS

nuBALL2 + PARIS

GOSIA

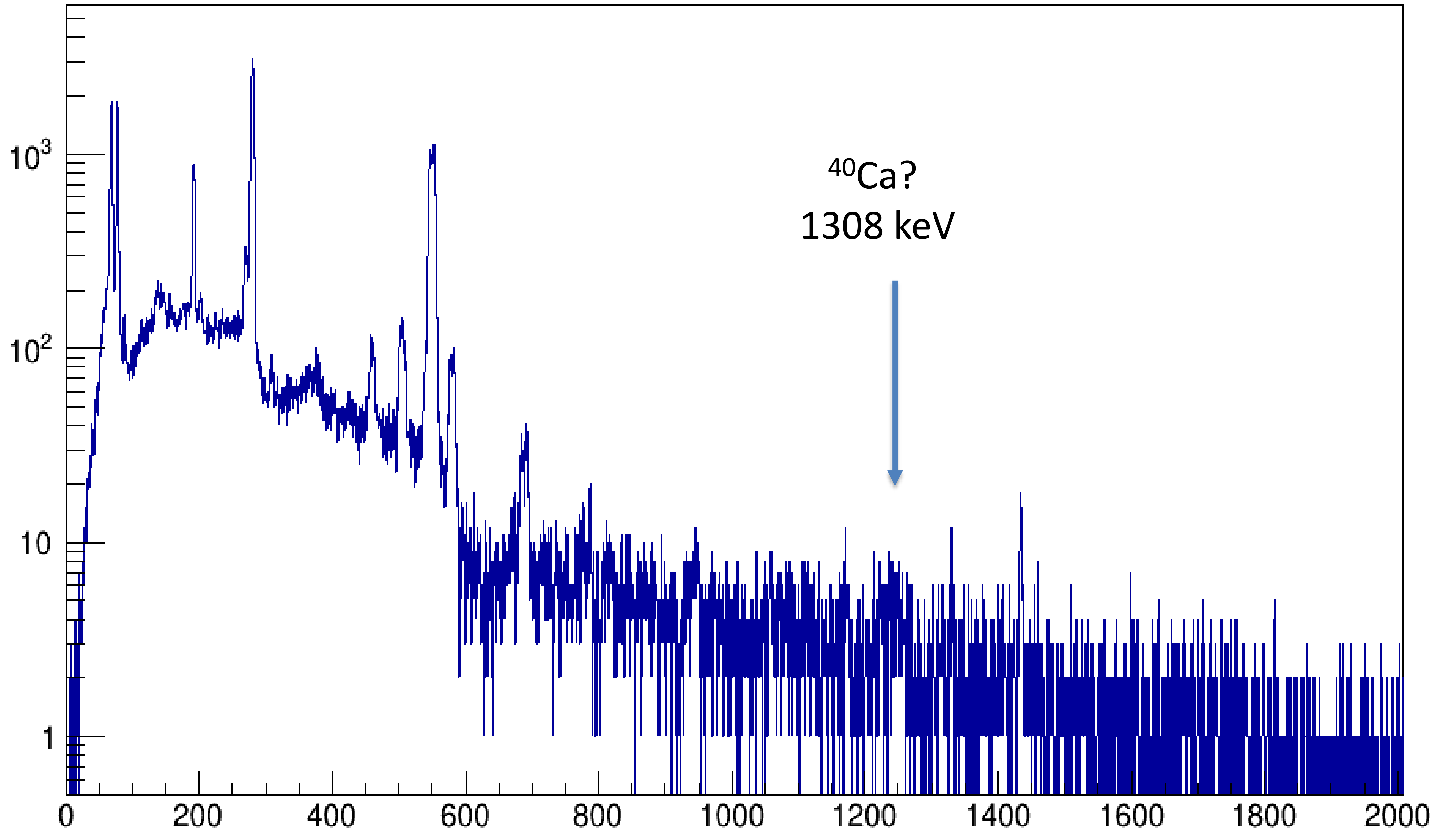
Transition	Energy [keV]	Counts/day
ND band transitions		
$2_1^+ \rightarrow 0_{GS}^+$	3905	115000
$2_1^+ \rightarrow 0_2^+$	553	250
$4_1^+ \rightarrow 2_1^+$	1375	8500
$6_1^+ \rightarrow 4_1^+$	1653	250
SD band transitions		
$2_{SD}^+ \rightarrow 0_{SD}^+$	417	200
$4_{SD}^+ \rightarrow 2_{SD}^+$	914	1200
$6_{SD}^+ \rightarrow 4_{SD}^+$	1432	50
SD→ND transitions		
$0_{SD}^+ \rightarrow 2_1^+$	1308	70000
$2_{SD}^+ \rightarrow 0_2^+$	2278	4000
$2_{SD}^+ \rightarrow 2_1^+$	1725	1500
$2_{SD}^+ \rightarrow 0_{GS}^+$	5630	17000
$4_{SD}^+ \rightarrow 2_1^+$	2639	2500
$4_{SD}^+ \rightarrow 4_1^+$	1264	70

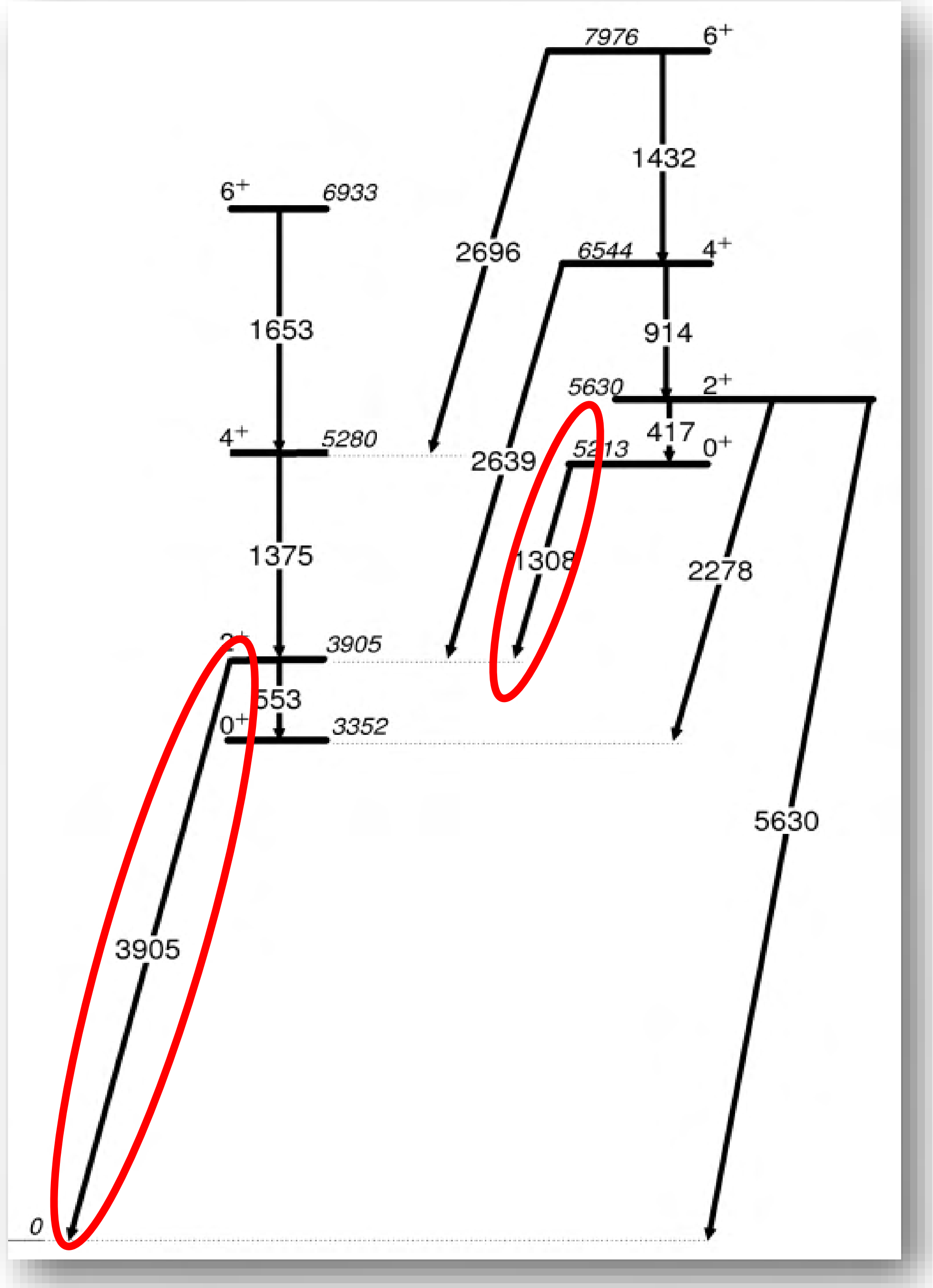
nuBALL2:
2 rings of 12+12 HPGe CLOVERS + ACS

PARIS:
LaBr3 / CeBr3 + NaI array
15 cm from the target

SiLCA DSSD (HIL, Uni of Warsaw):
32 sectors + 16 rings
125-152°

Coulomb excitation of ^{40}Ca – IJC Lab, Orsay

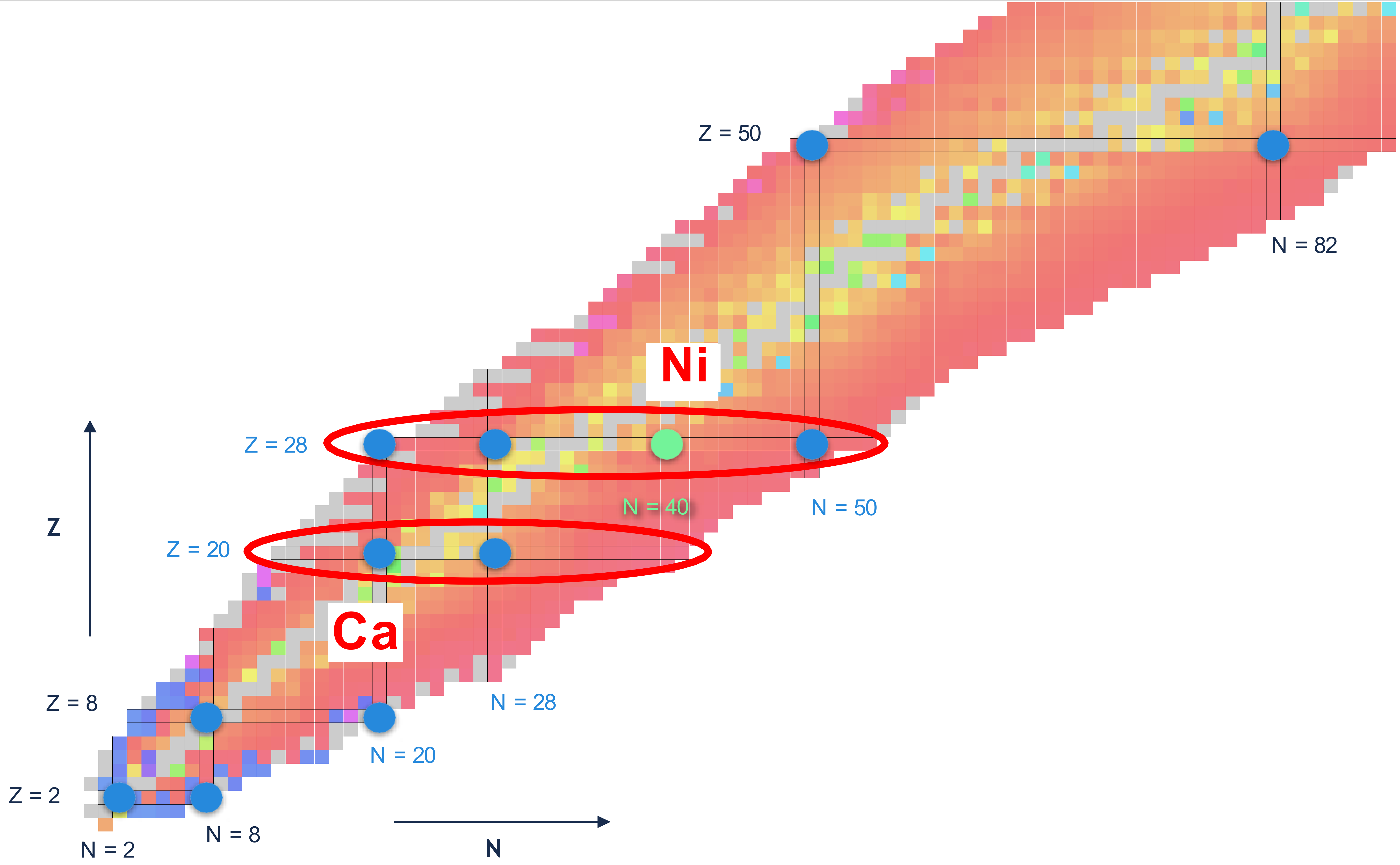




2 days of the data taking only

Analysis is ongoing (HPGe clover + DSSD part)
COULEX – to be redone in another lab

^{40}Ca (Z=N=20) vs ^{56}Ni (Z=N=28)



N=Z nuclei: Z/N~20 and Z/N~28 – similar?

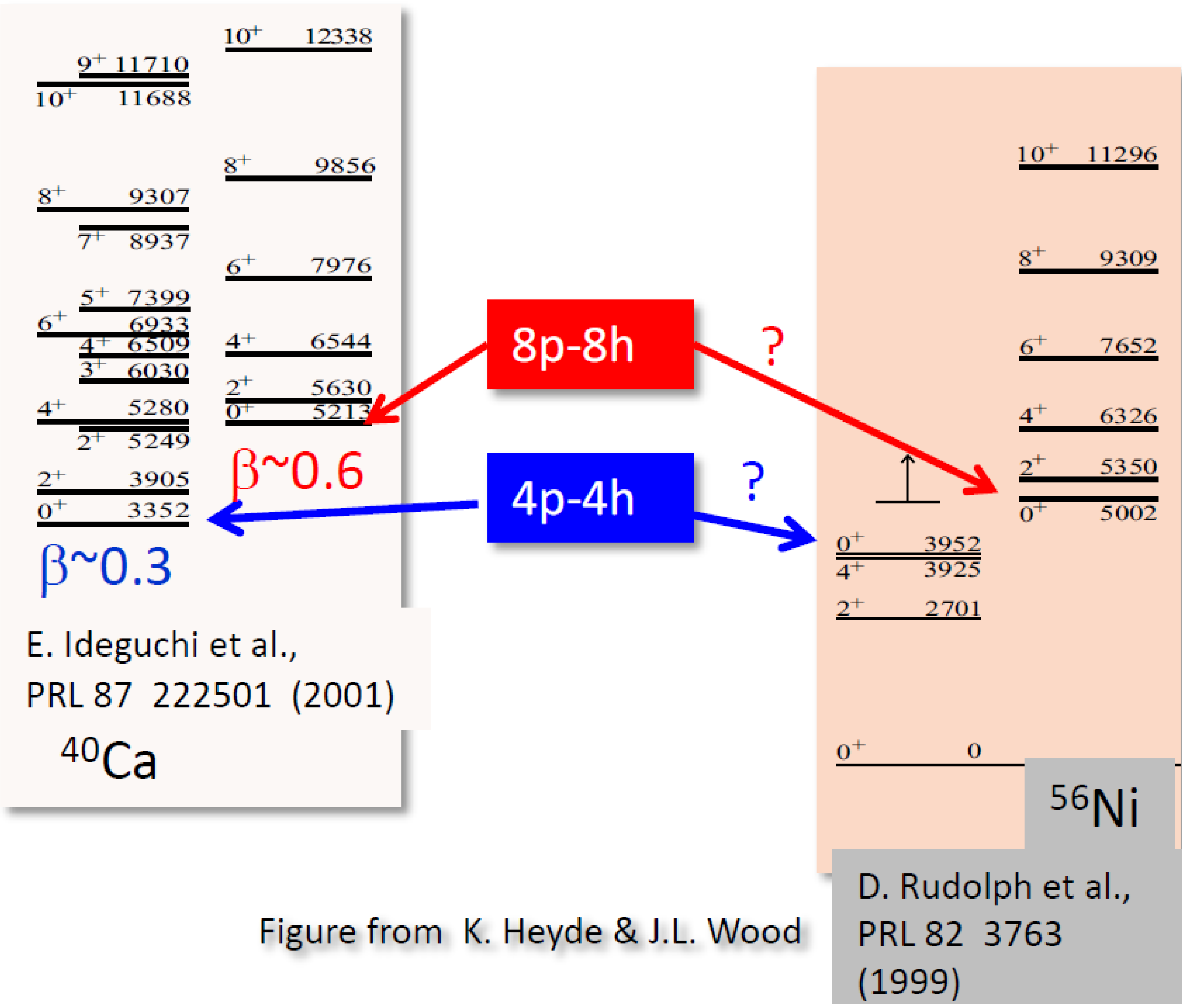
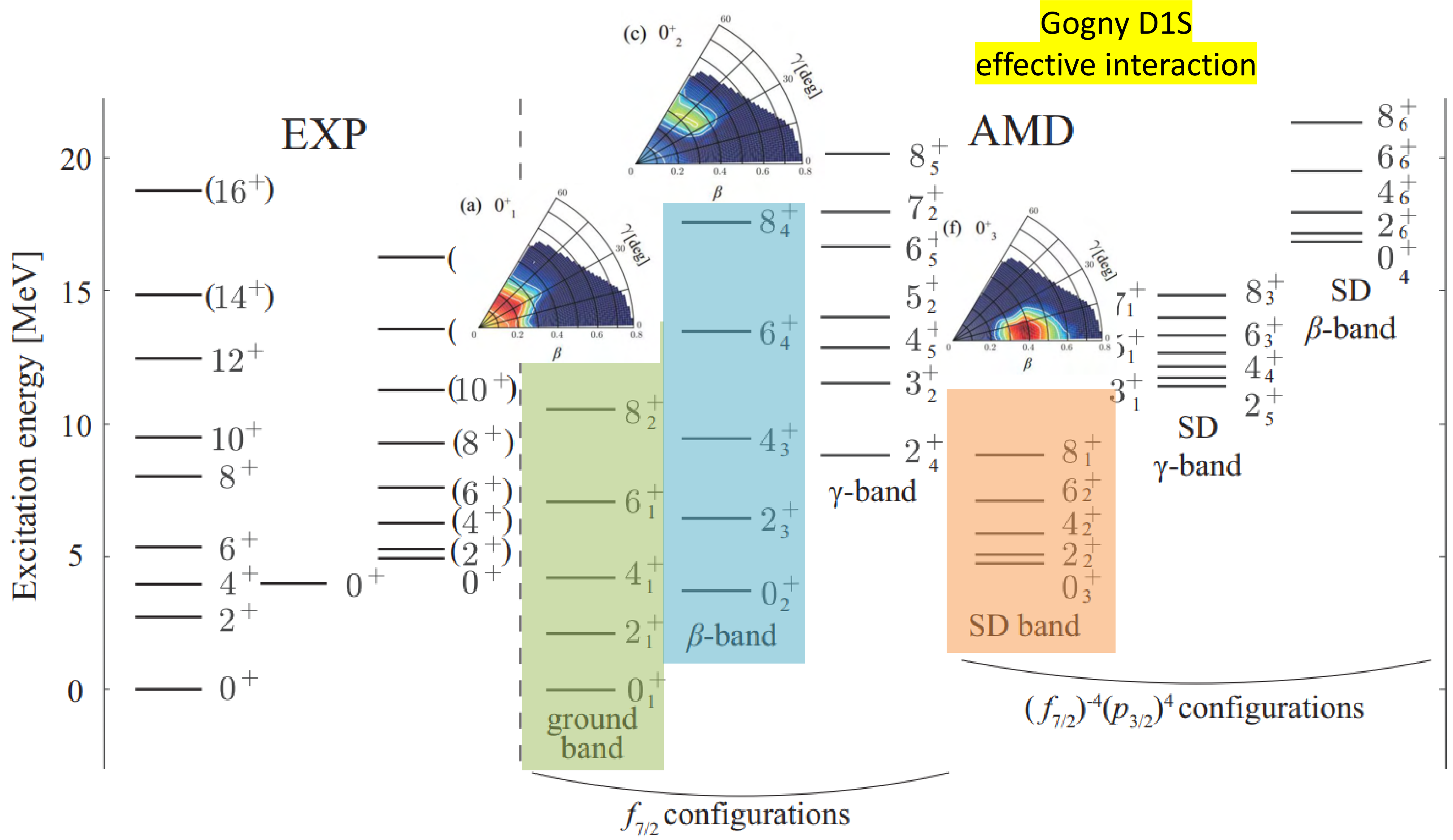


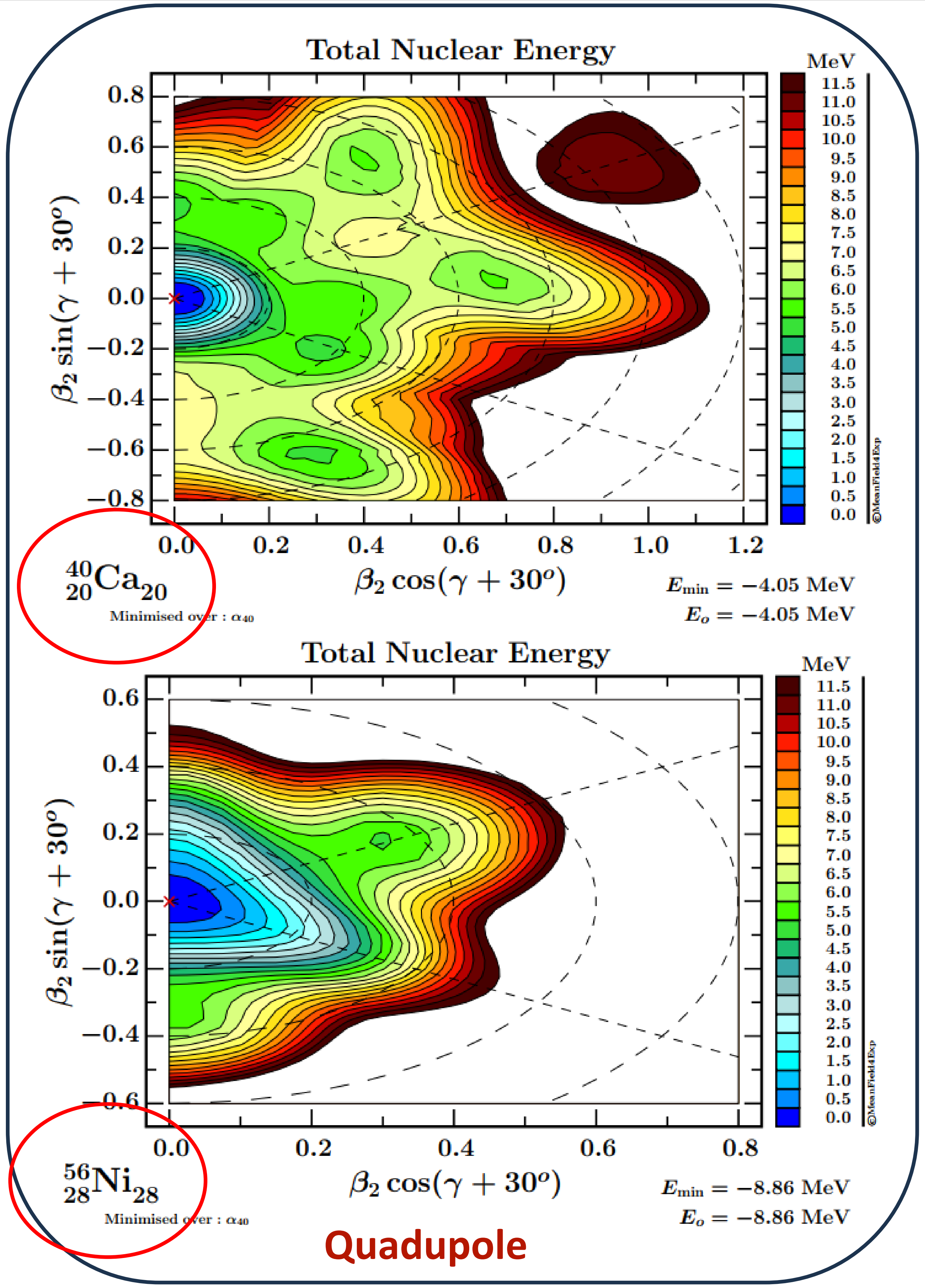
Figure from K. Heyde & J.L. Wood



Y. Chiba and M. Kimura
PRC 89, 054313 (2014)

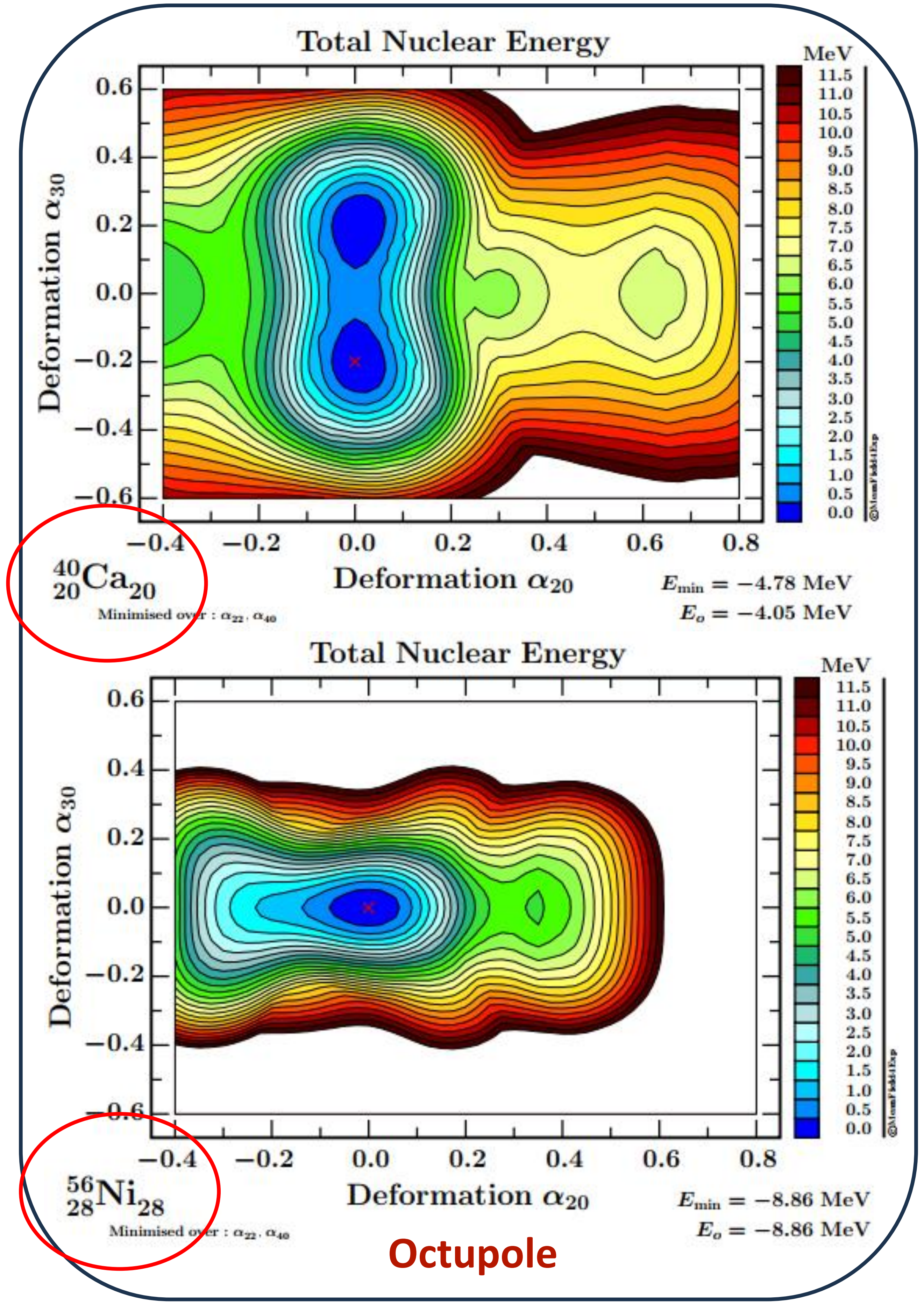
- ➔ ^{56}Ni is quite soft against oblate deformation
- ➔ The shell gap easily disappears by prolate deformation, which leads to **the coexistence** of the almost spherical ground band, excited β and γ bands, and a prolate superdeformed band with $(f7/2)^{-m}(p3/2)^{m}$ configurations within the small excitation energies.

N=Z nuclei: Z/N~20 and Z/N~28 – similar?

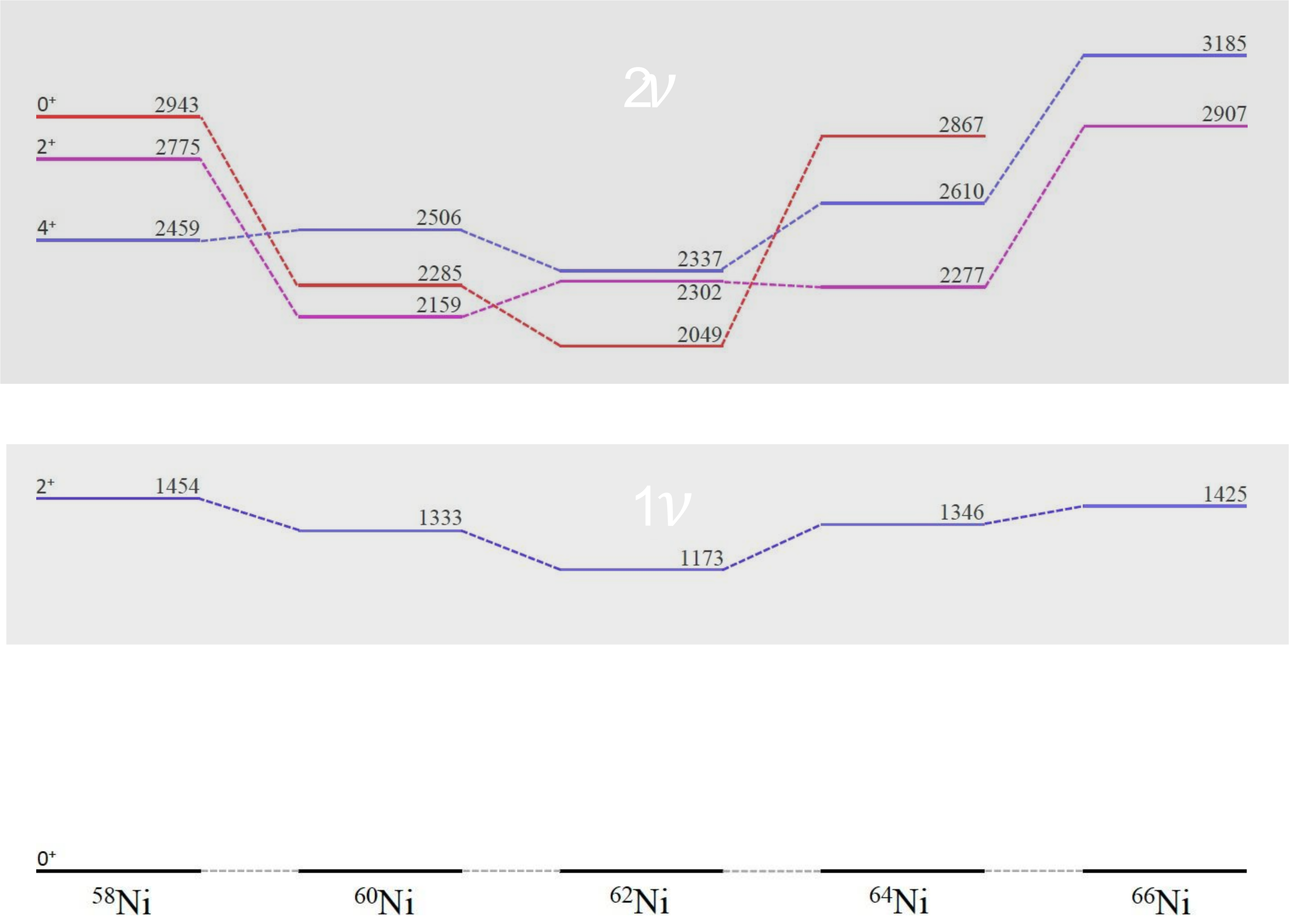


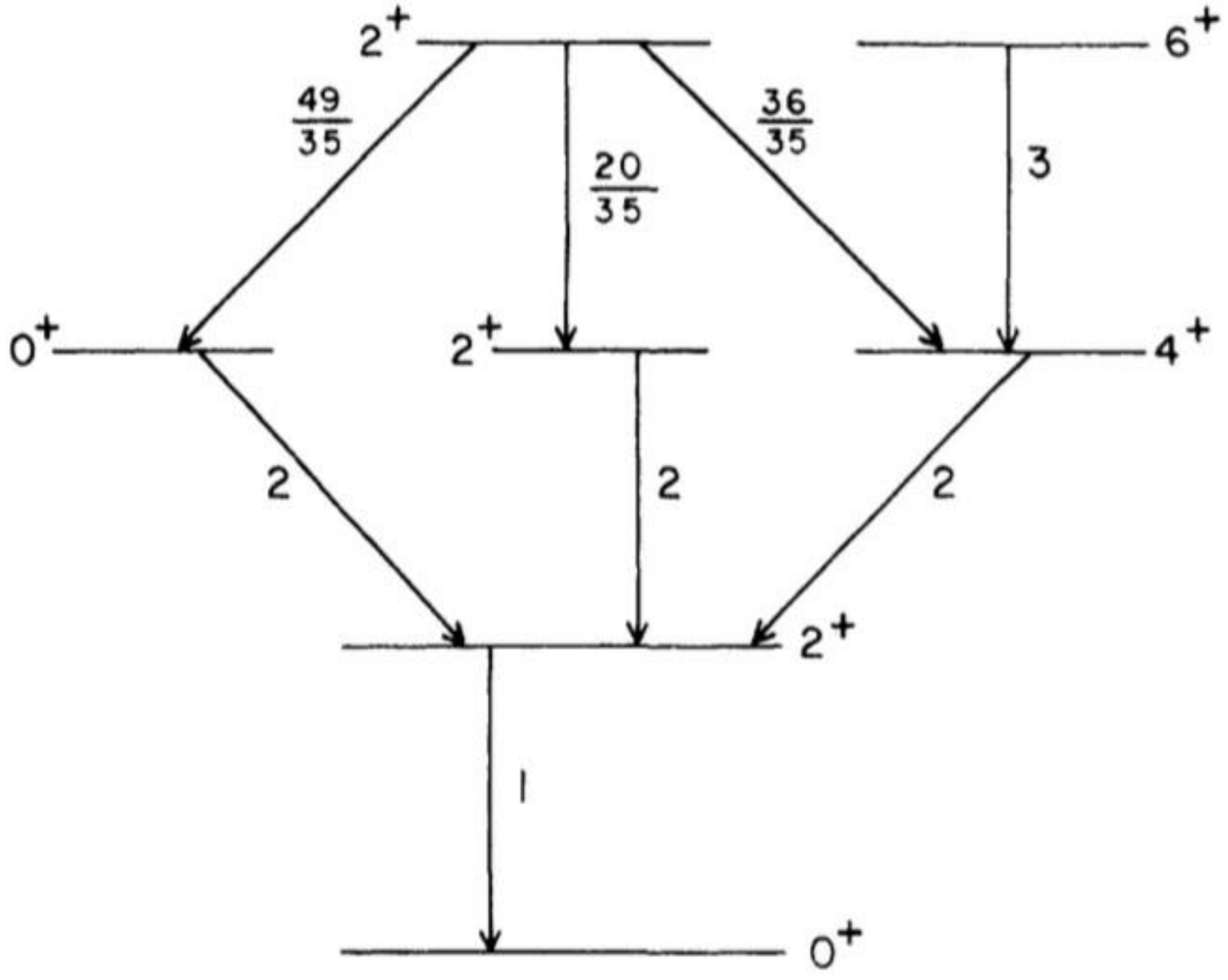
- A phenomenological mean-field Hamiltonian
- Woods-Saxon interaction
- universal Woods-Saxon parametrization

I. Dedes
(Institute of Nuclear Physics, Polish Academy of Sciences, Kraków, PL)



Nickel isotopes – vibrations?



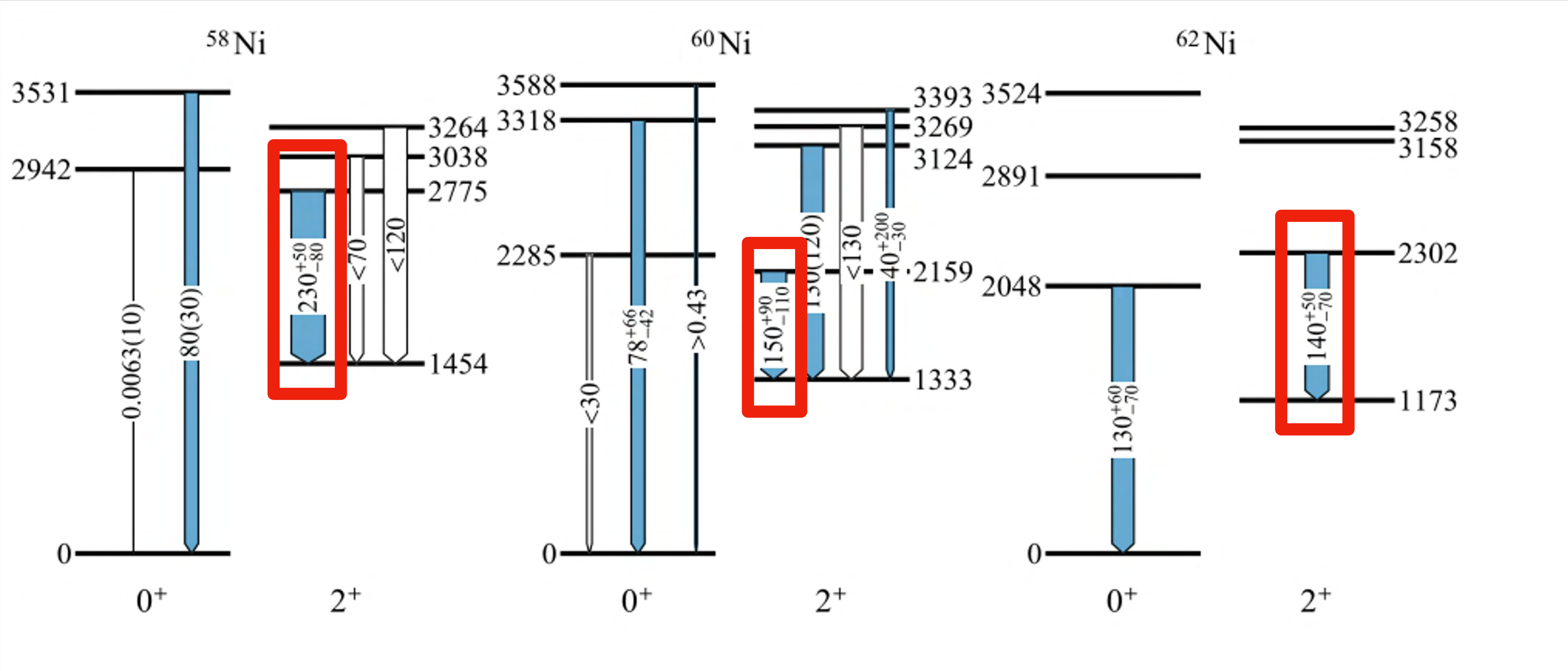


B(E2) VALUES FOR DECAY OF MULTI-PHONON STATES

Transition probabilities and Qs values needed
Not only the level scheme
but also the structure

Extremes of E0 transitions in the Ni chain

L.J. Evitts et al., Phys. Rev. C 99 (2019) 024306.

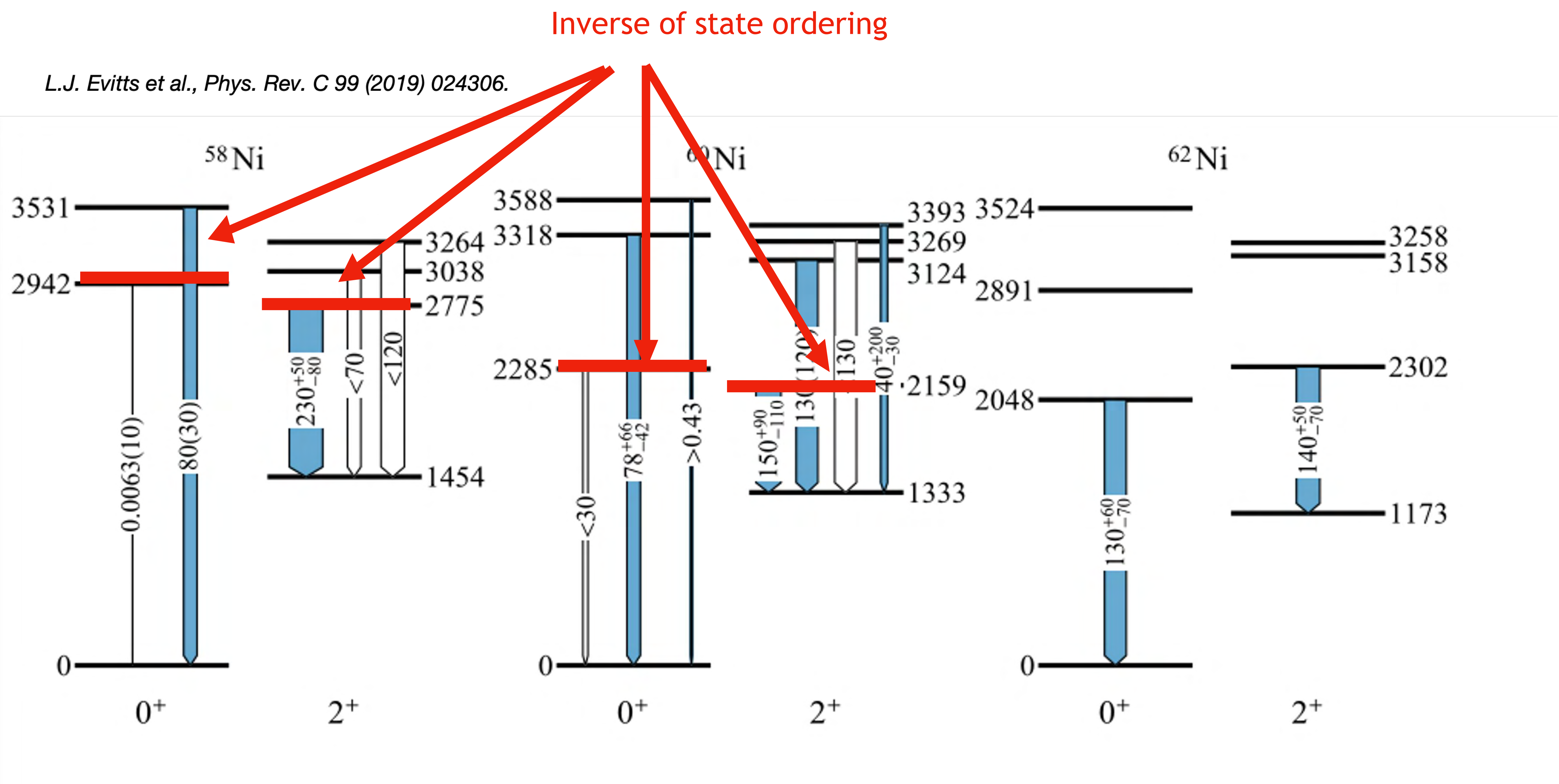


The largest $\rho^2(2_2^+ \text{->} 2_1^+)$ values in medium and heavy nuclei reported to date - BREAKING the vibrational picture

A spherical vibrator - the E0 transitions are forbidden if the change in phonon number is one: 2_2^+ CANNOT BE a 2ν STATE

Extremes of E0 transitions in the Ni chain

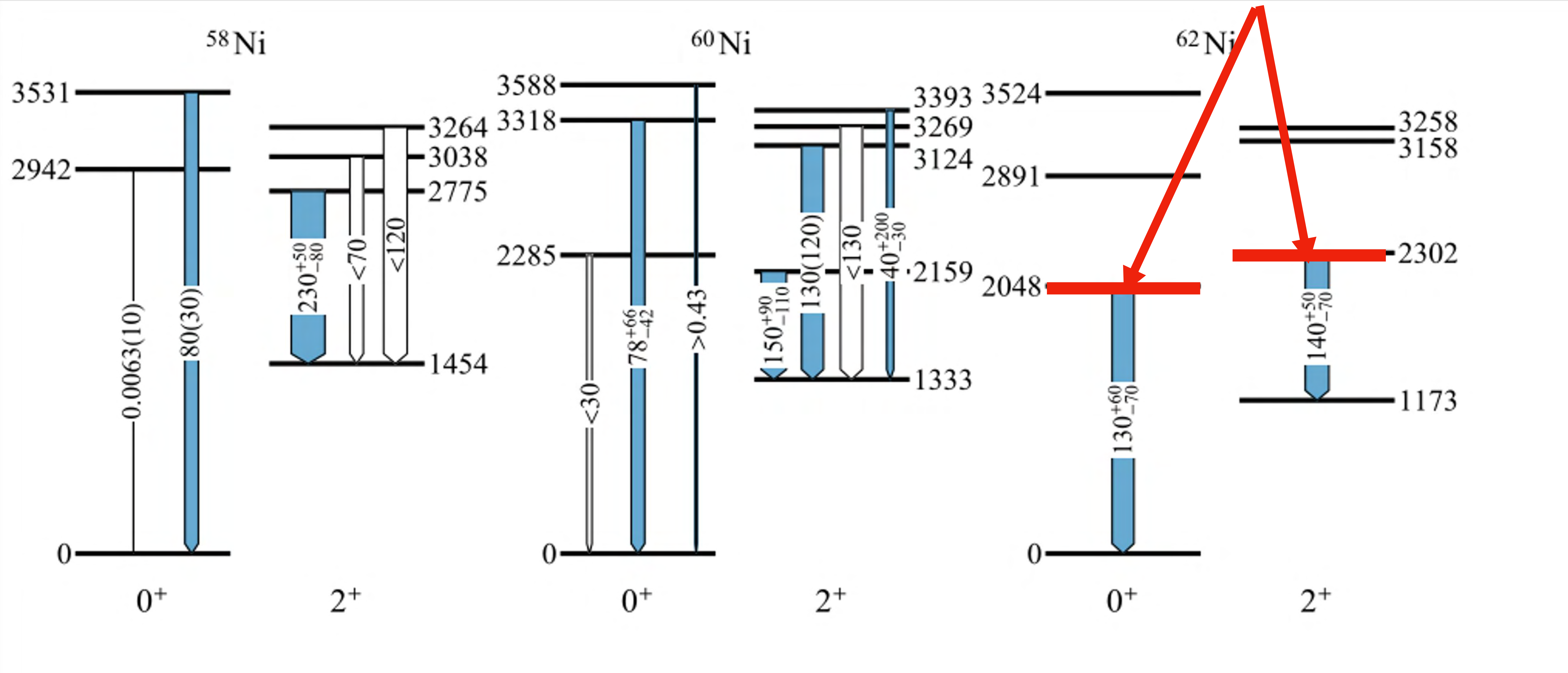
L.J. Evitts et al., Phys. Rev. C 99 (2019) 024306.



Extremes of E0 transitions in the Ni chain

L.J. Evitts et al., Phys. Rev. C 99 (2019) 024306.

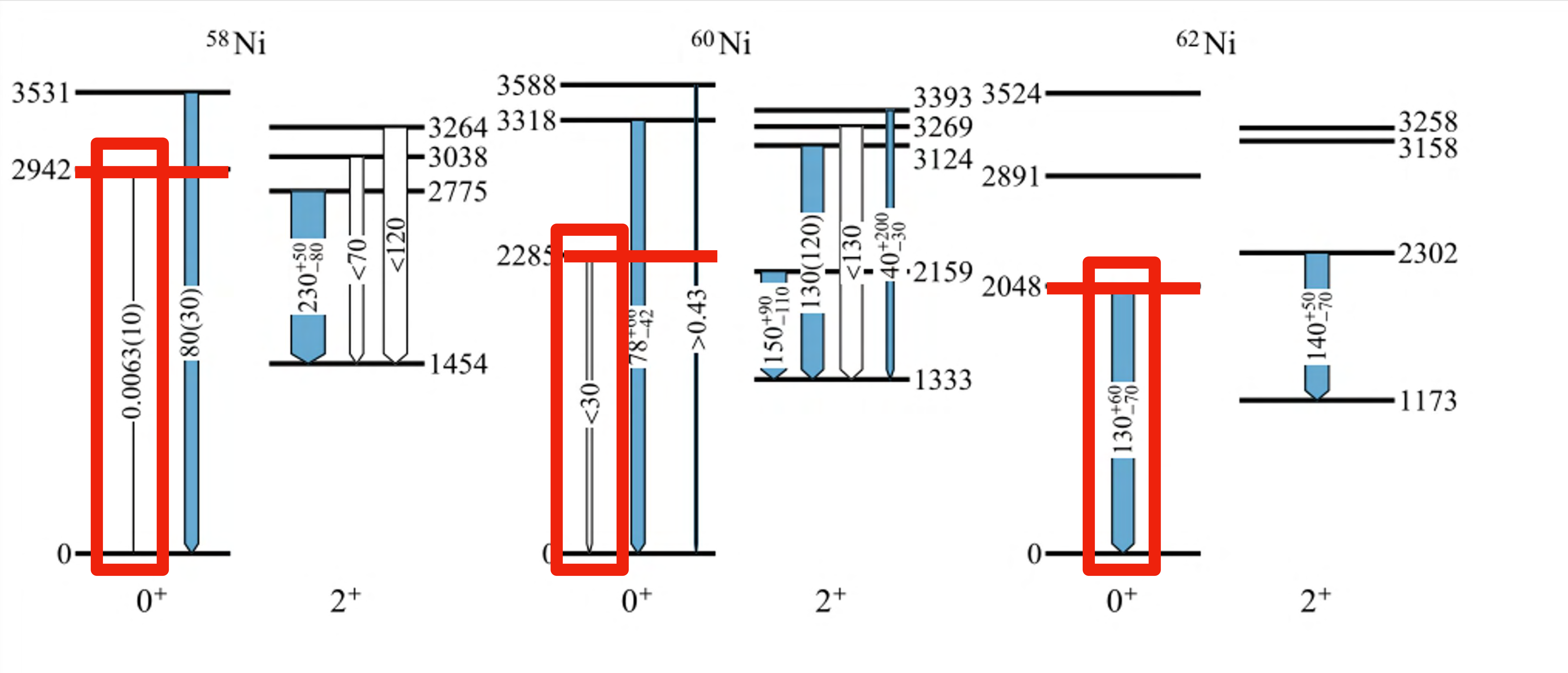
Sudden change of ordering - change of structure



Extremes of E0 transitions in the Ni chain

L.J. Evitts et al., Phys. Rev. C 99 (2019) 024306.

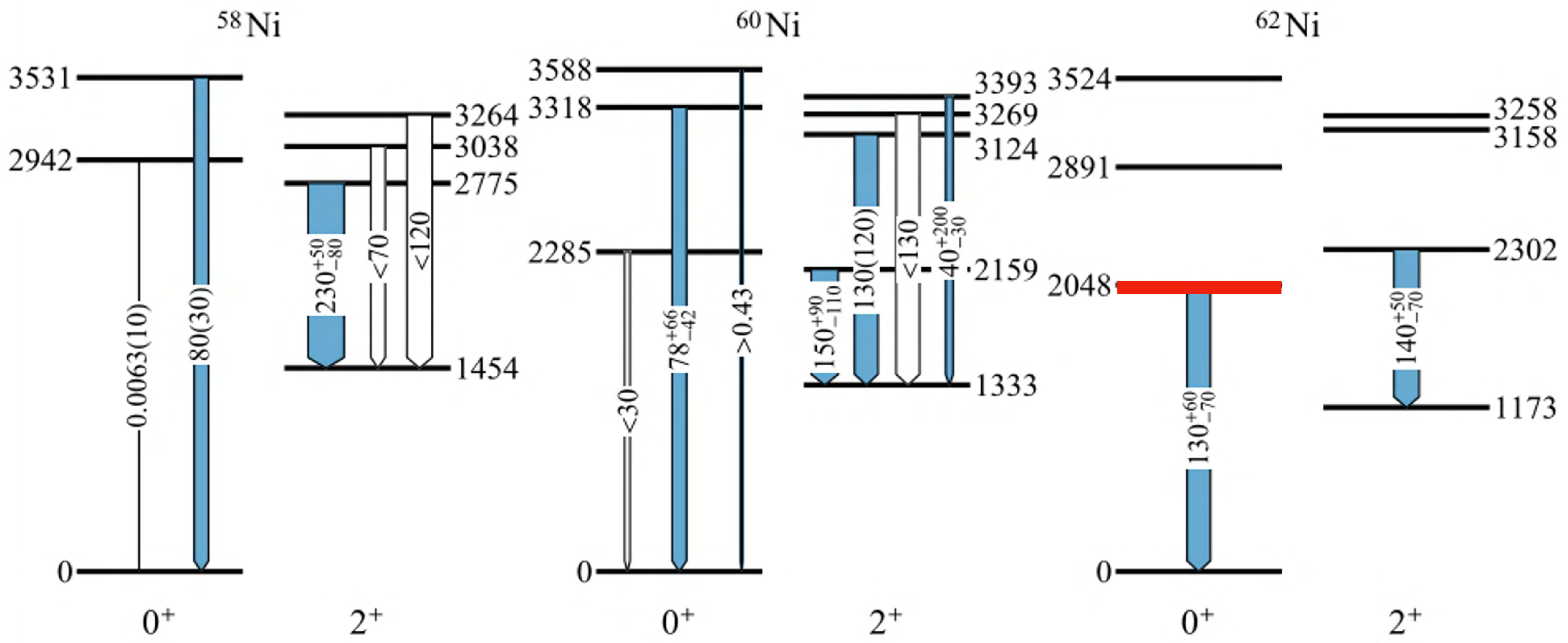
Large B(E0) between 0^+ states in ^{62}Ni



Extremes of E0 transitions in the Ni chain

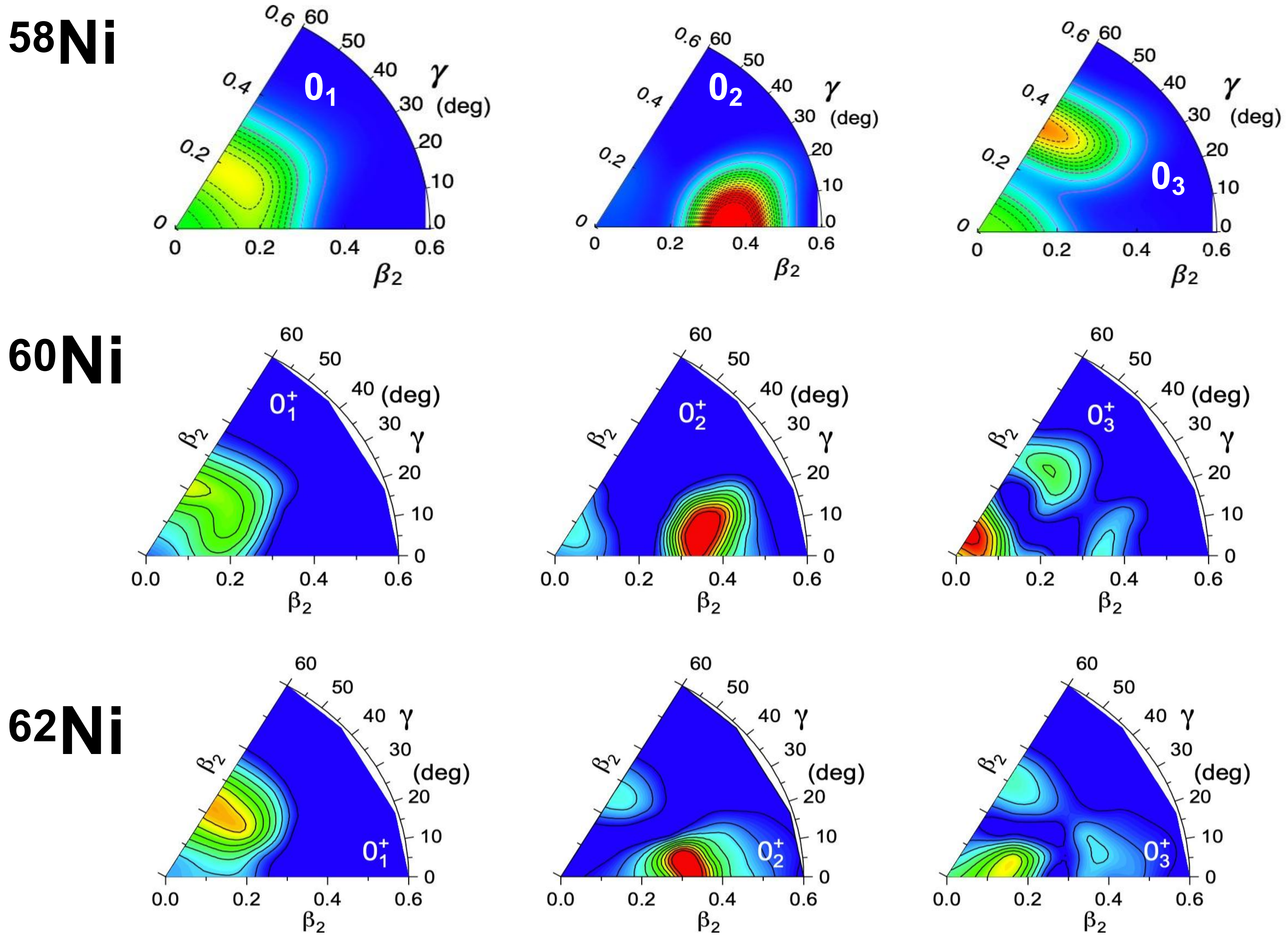
L.J. Evitts et al., Phys. Rev. C 99 (2019) 024306.

Superdeformed band? *4p-4h* excitation



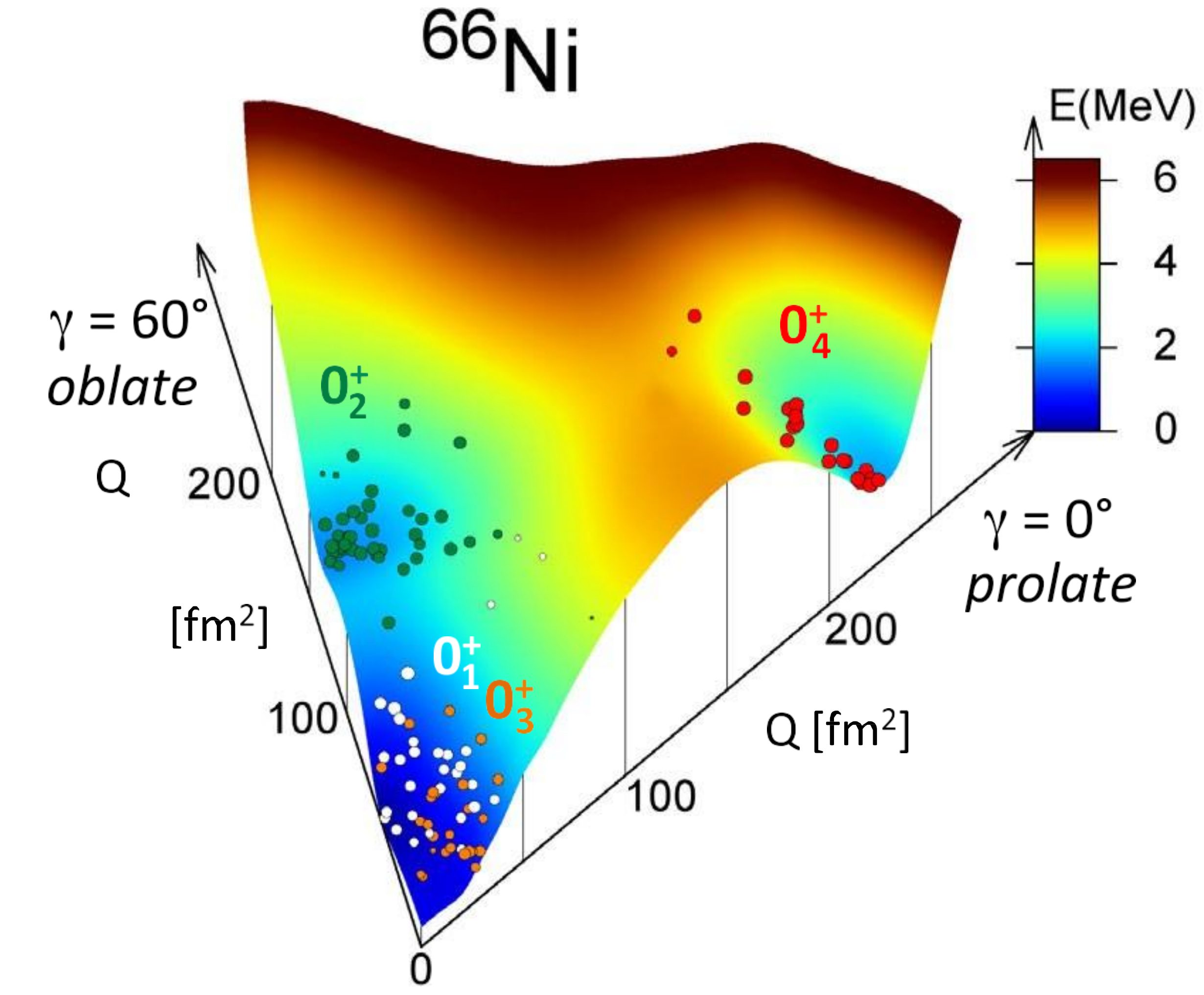
Theoretical perspective

Collective wave functions BMF (SCCM-D1S Gogny triaxial calculations)
T. Rodriguez



Multiple shape coexistence

Shape coexistence and shape isomerism established in heavier Ni isotopes, but their role in the vicinity of 56Ni has to be explored.

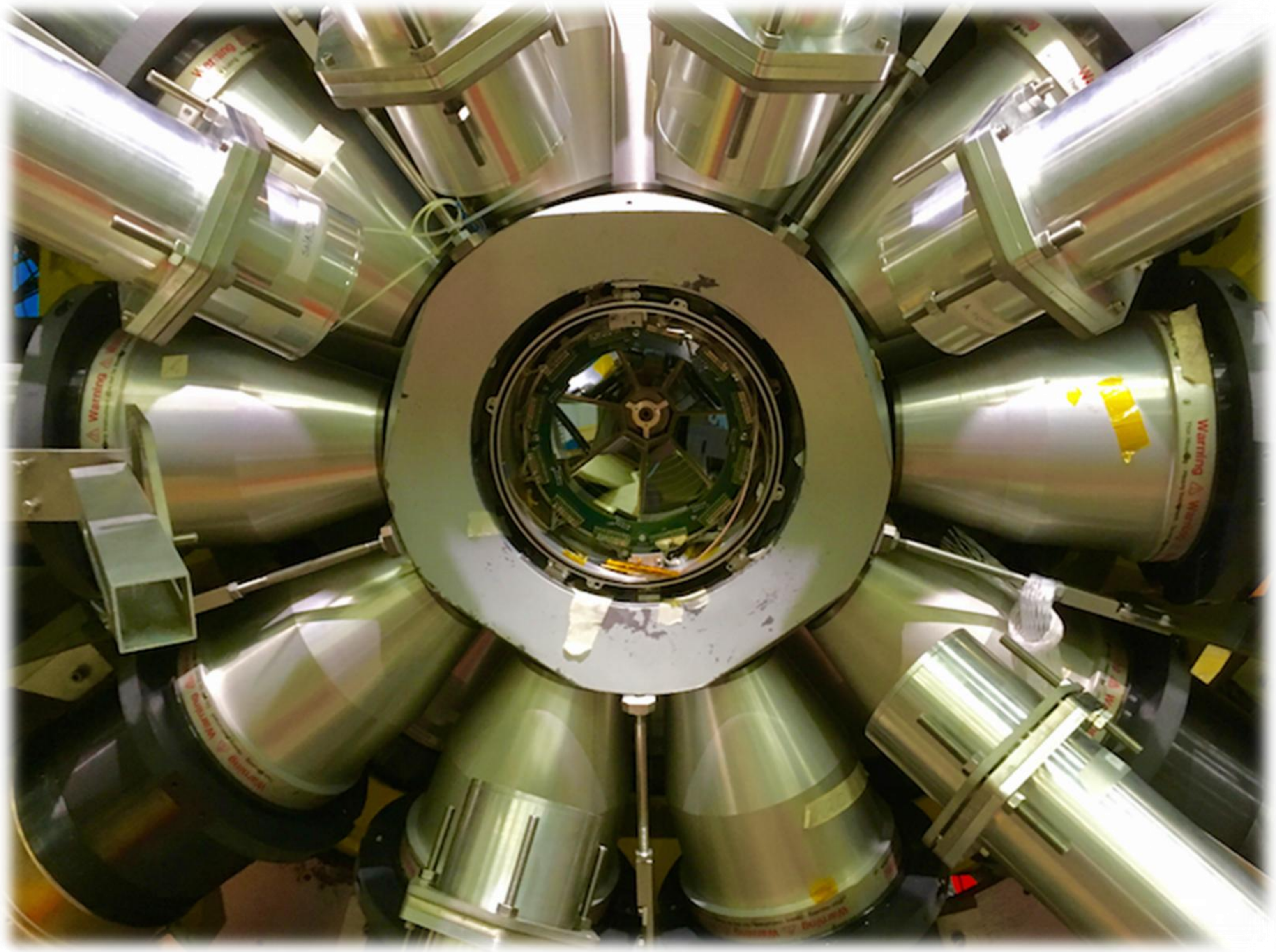


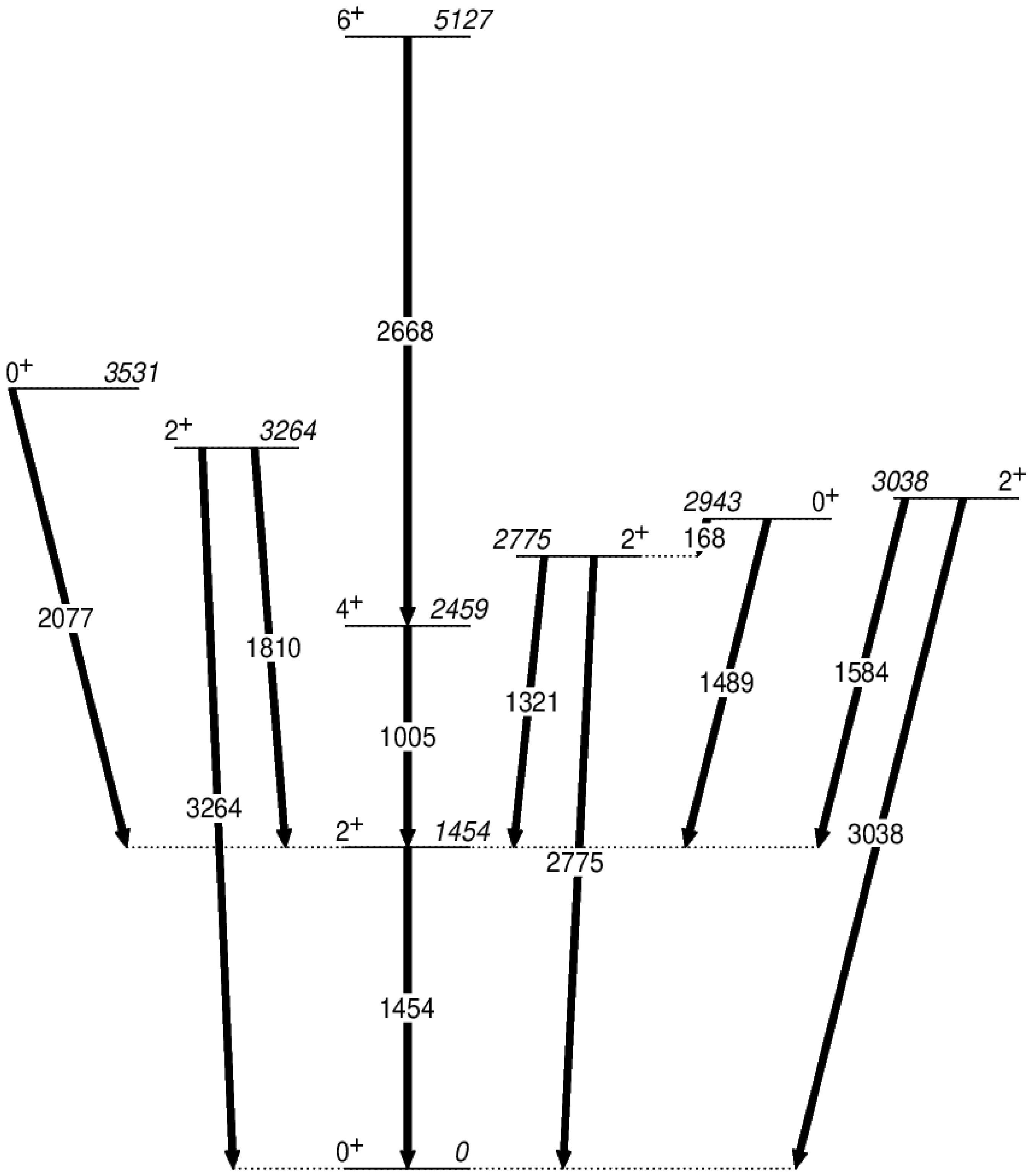
S. Leoni *et al.*, PRL **118** (2017) 162502
N. Mărginean *et al.*, PRL **125** (2020) 102502

^{58}Ni – INFN LNL

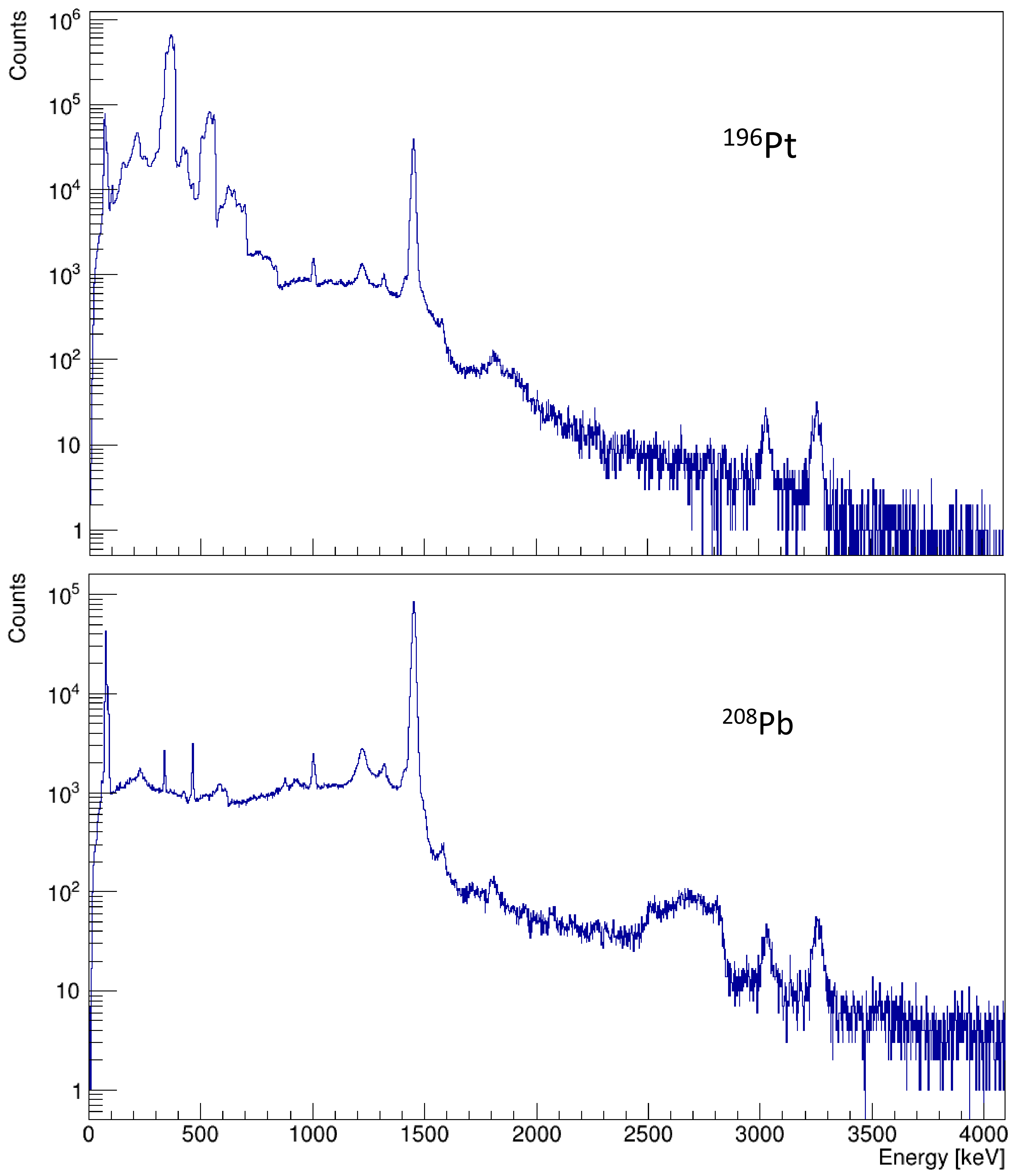
- February 2020
- ^{58}Ni beam, 230 MeV, I ~1 pnA
- ^{208}Pb, 1 mg/cm^2
- ^{196}Pt, 1 mg/cm^2

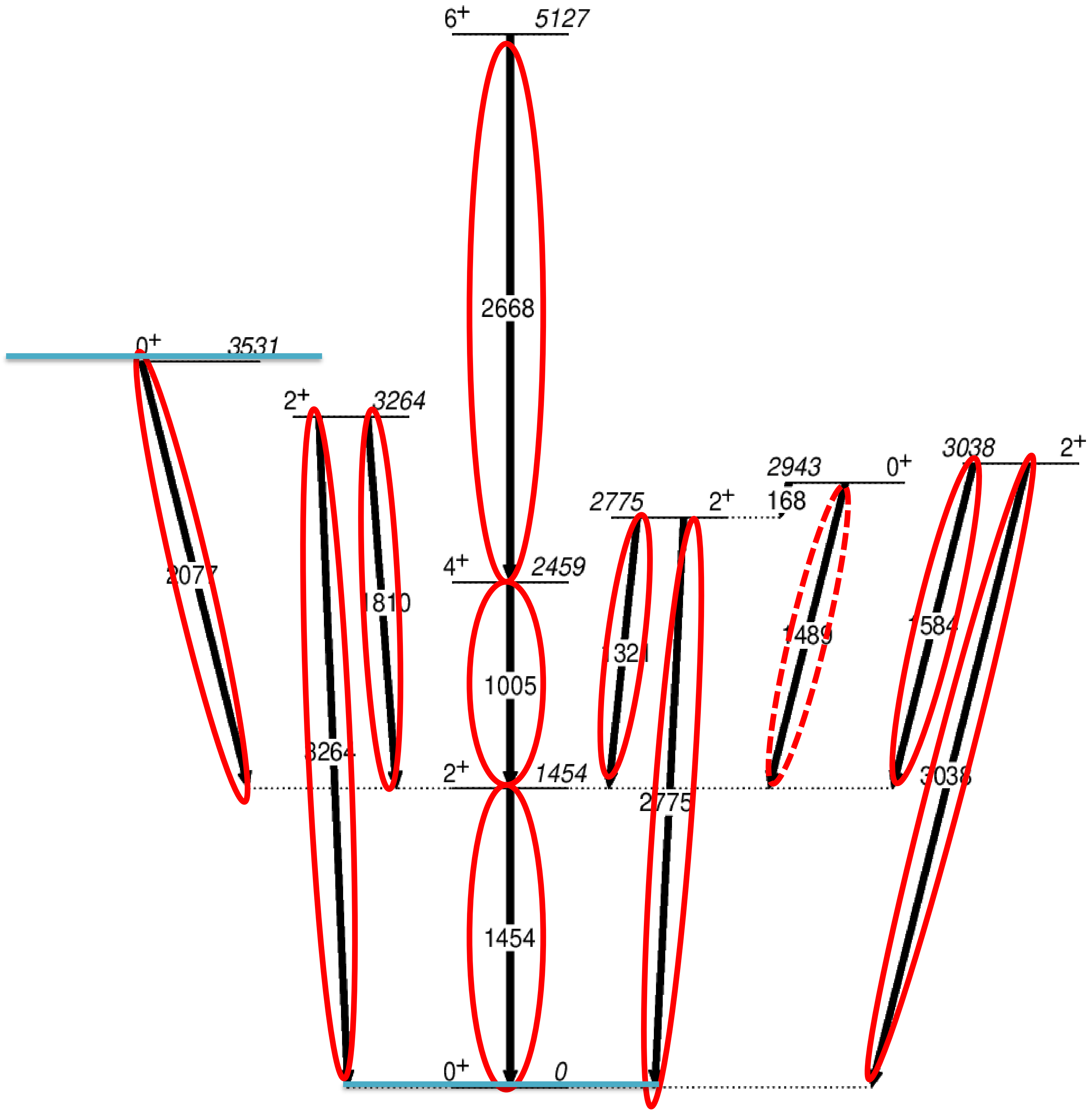
- GALILEO, 24 HPGe, ACS
- SPIDER, 7 sectors, 8 rings : 123-161°
- 7 $LaBr_3$ detectors





^{58}Ni – INFN LNL





KHK, analysis ongoing, to be published

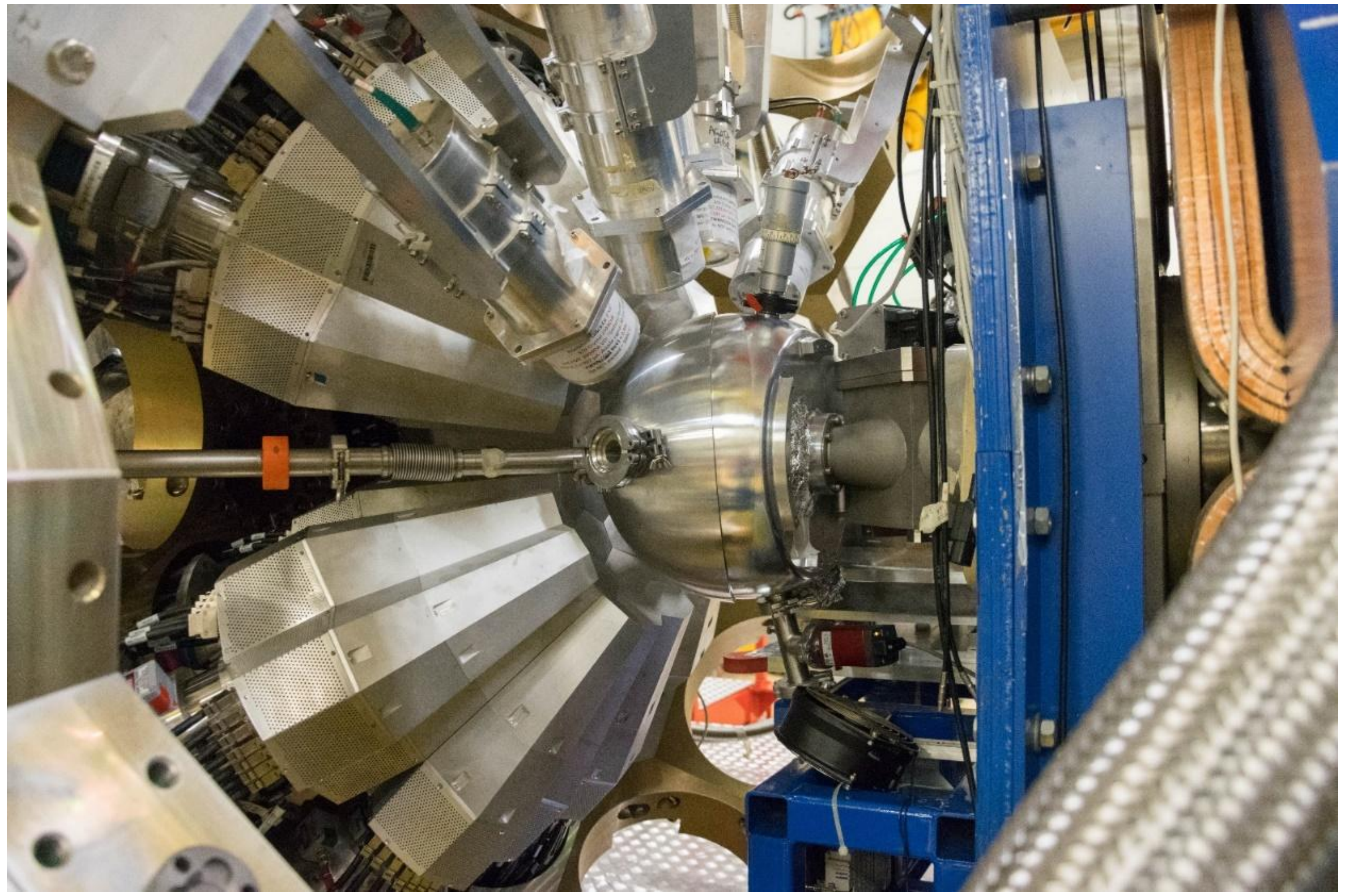
^{60}Ni – INFN LNL

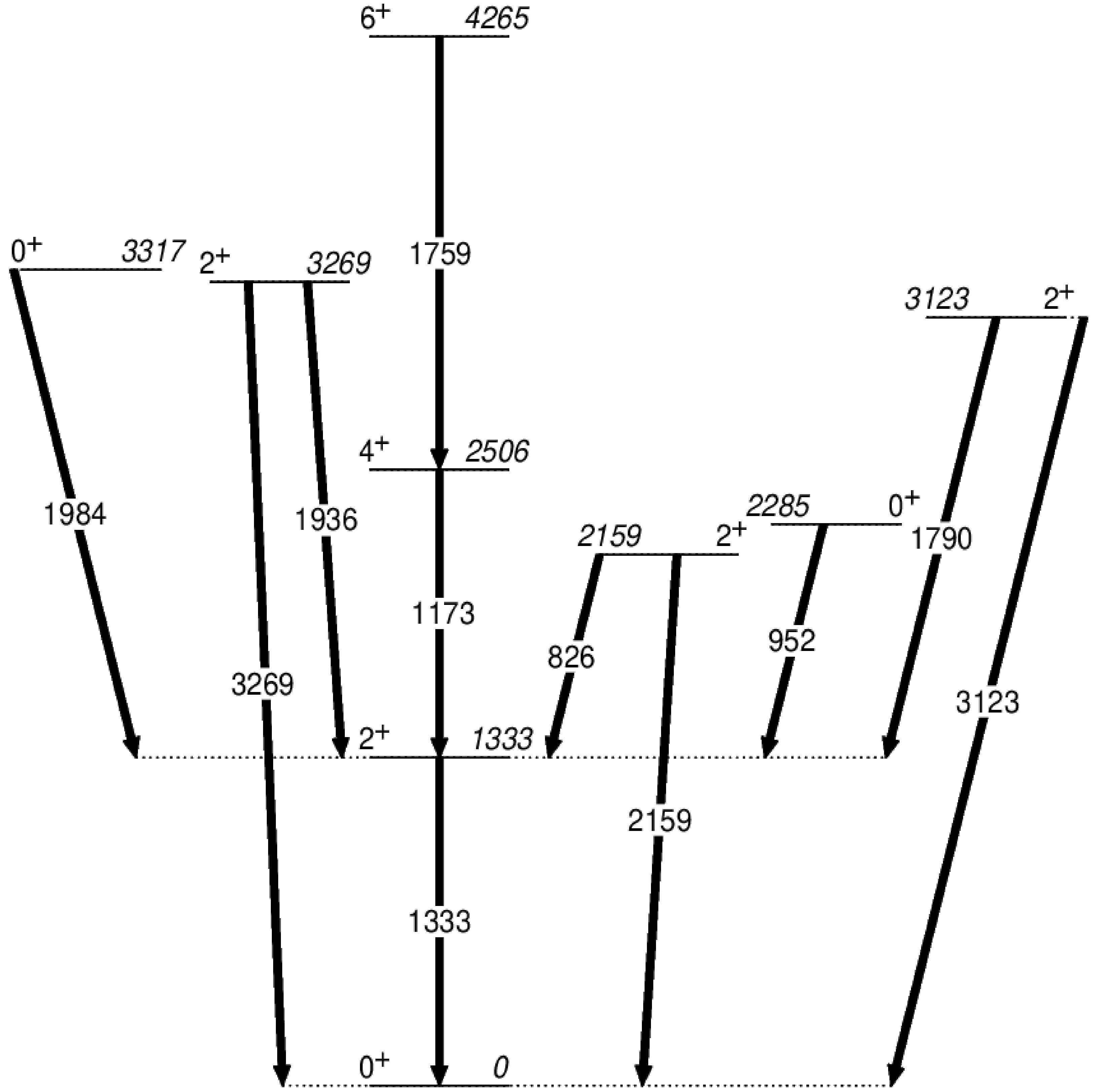
Heavy Ion Laboratory

INFN FIRENZE
Istituto Nazionale di Fisica Nucleare
Sezione di Firenze

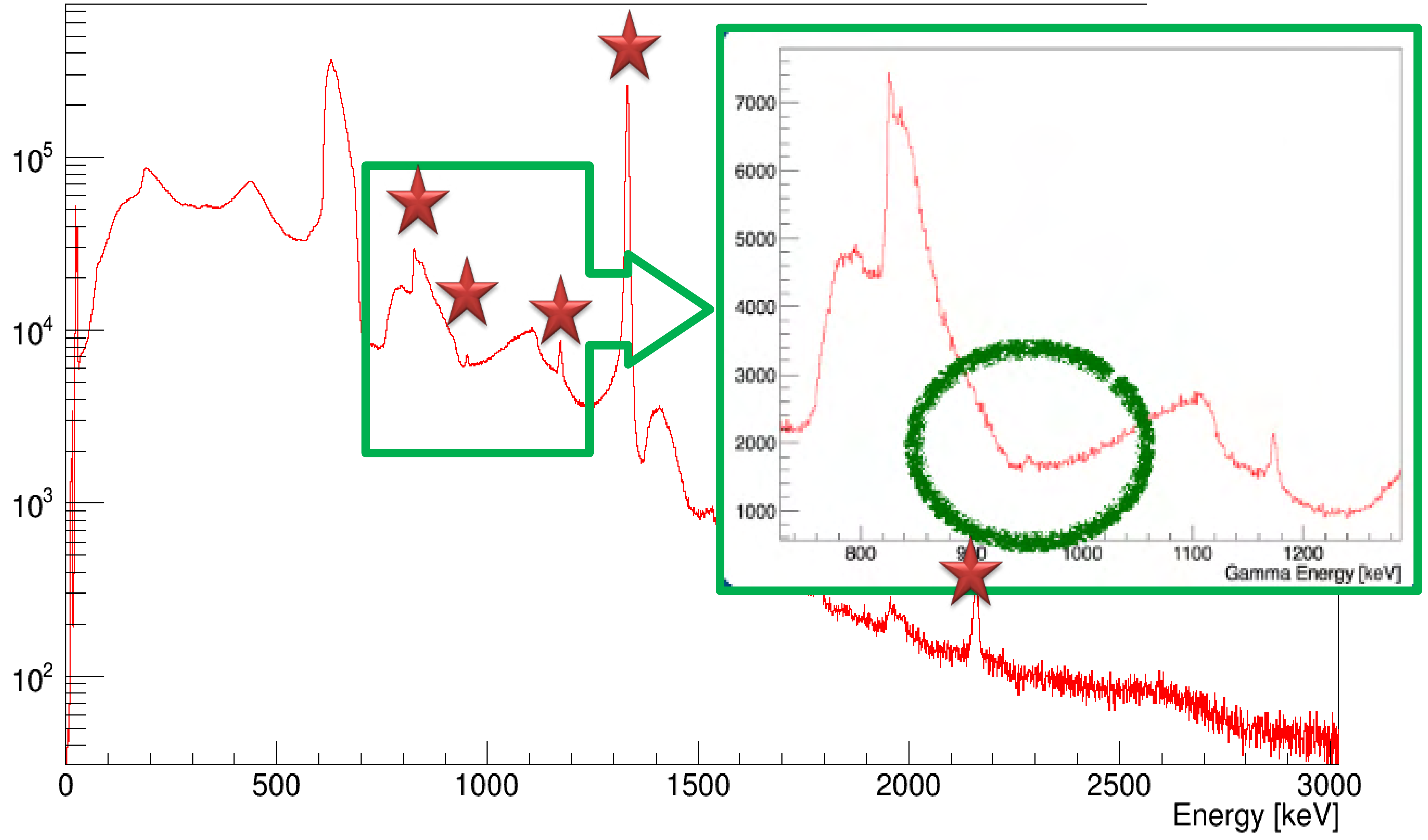
- June and October 2022
- ^{60}Ni beam, 187 MeV, I ~2 pnA
- ^{110}Cd, 0.9 mg/cm2

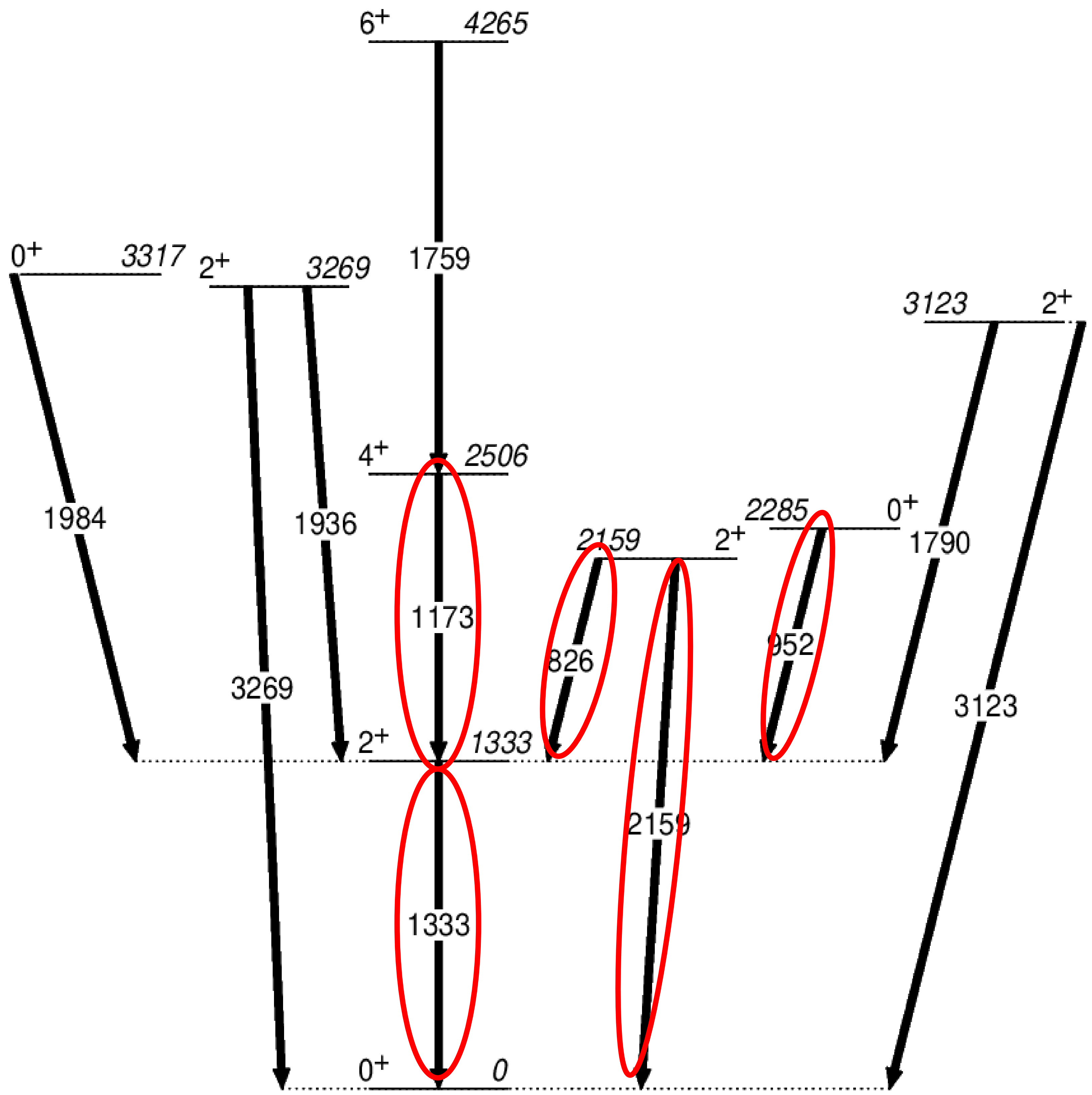
- AGATA, 11 triple clusters
- SPIDER, 7 sectors, 8 rings : 128-160°
- 7 $LaBr_3$ detectors





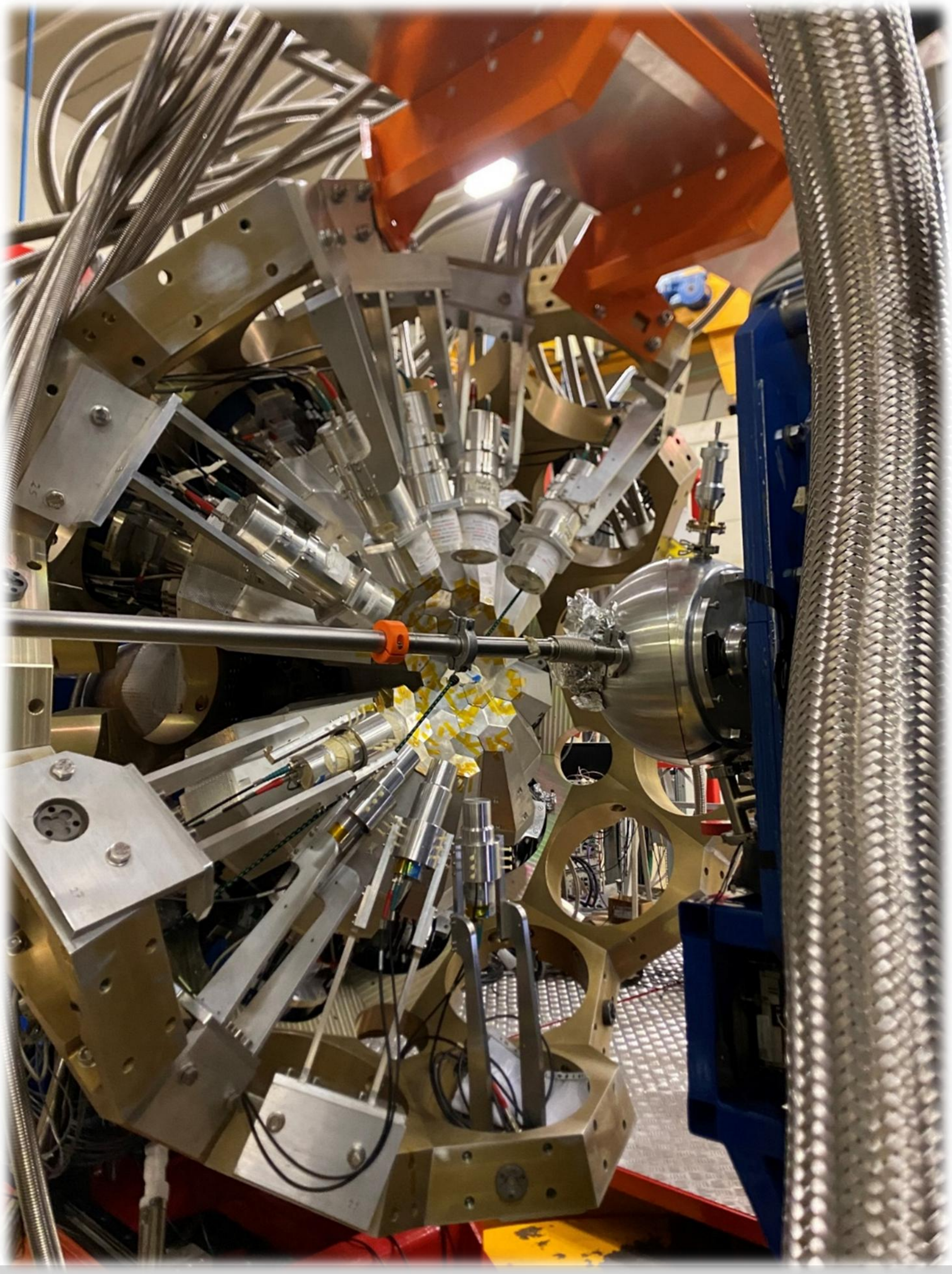
^{60}Ni – INFN LNL

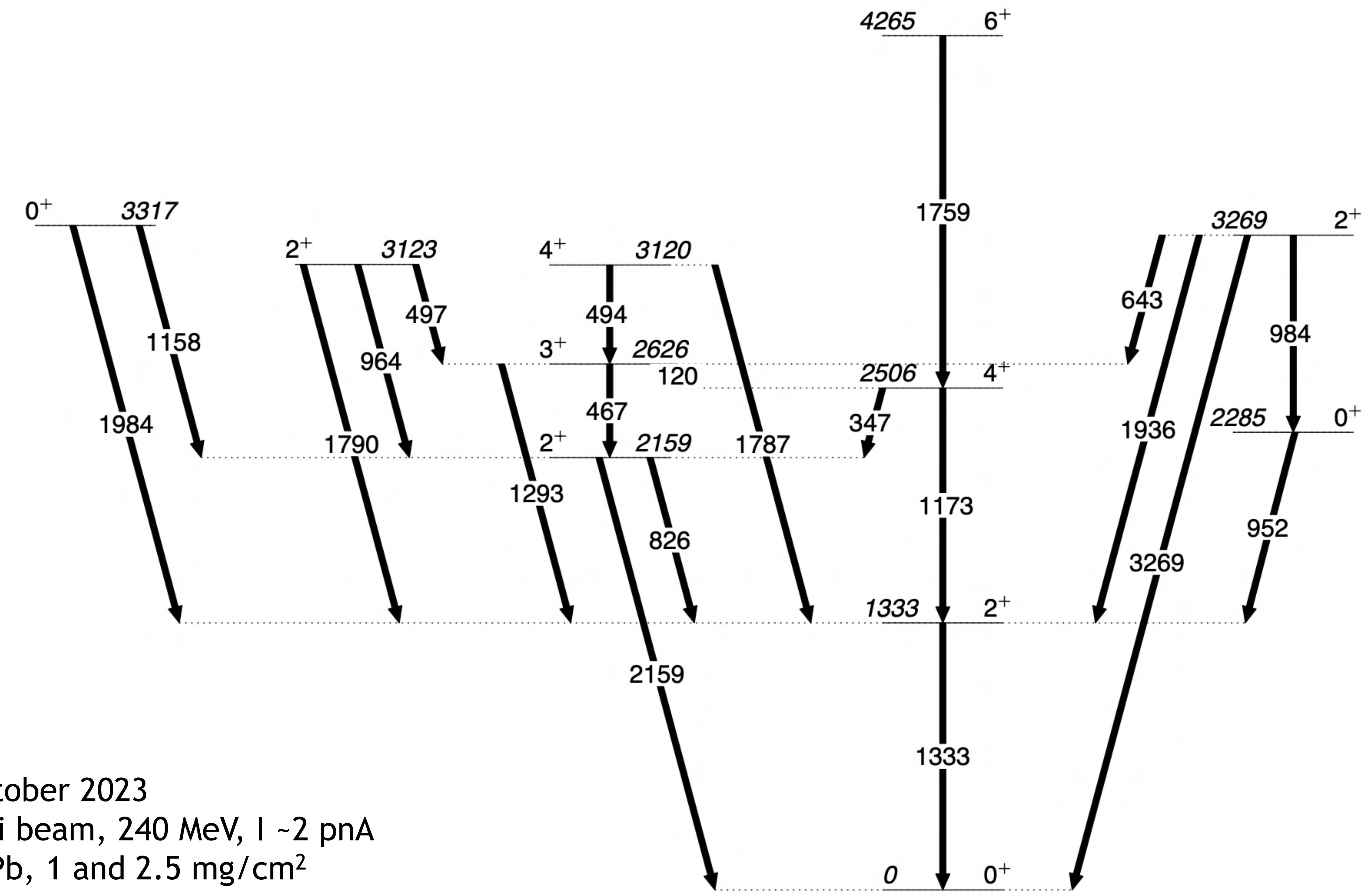




- Cd excitation overlapped with the most important lines
- Another (dedicated) experiment needed

^{60}Ni – INFN LNL – a dedicated run





- October 2023
- ^{60}Ni beam, 240 MeV, I ~2 pnA
- ^{208}Pb, 1 and 2.5 mg/cm^2

- AGATA, 13 triple clusters
- SPIDER, 7 sectors, 8 rings : 128-160°

^{60}Ni – INFN LNL – a dedicated run

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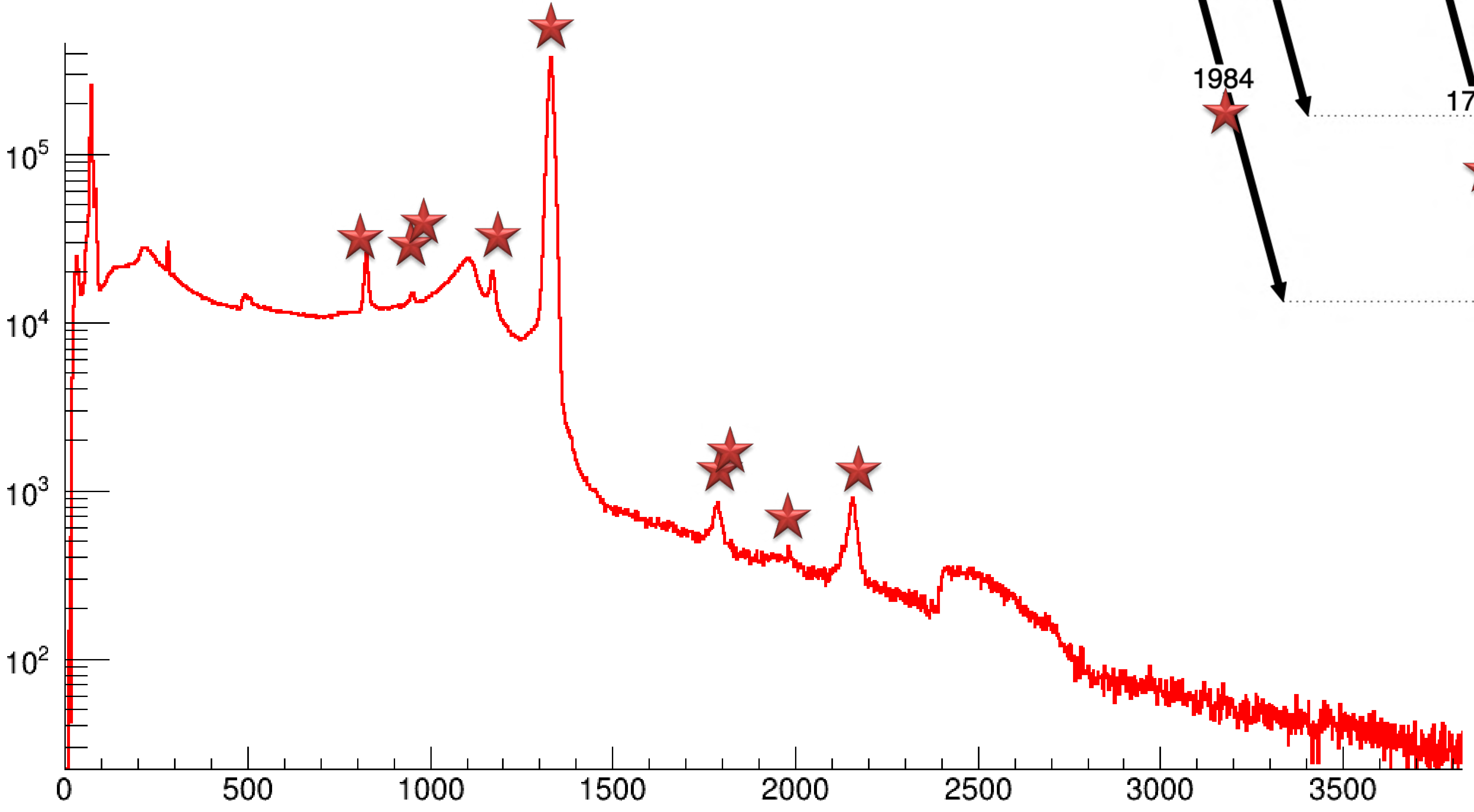
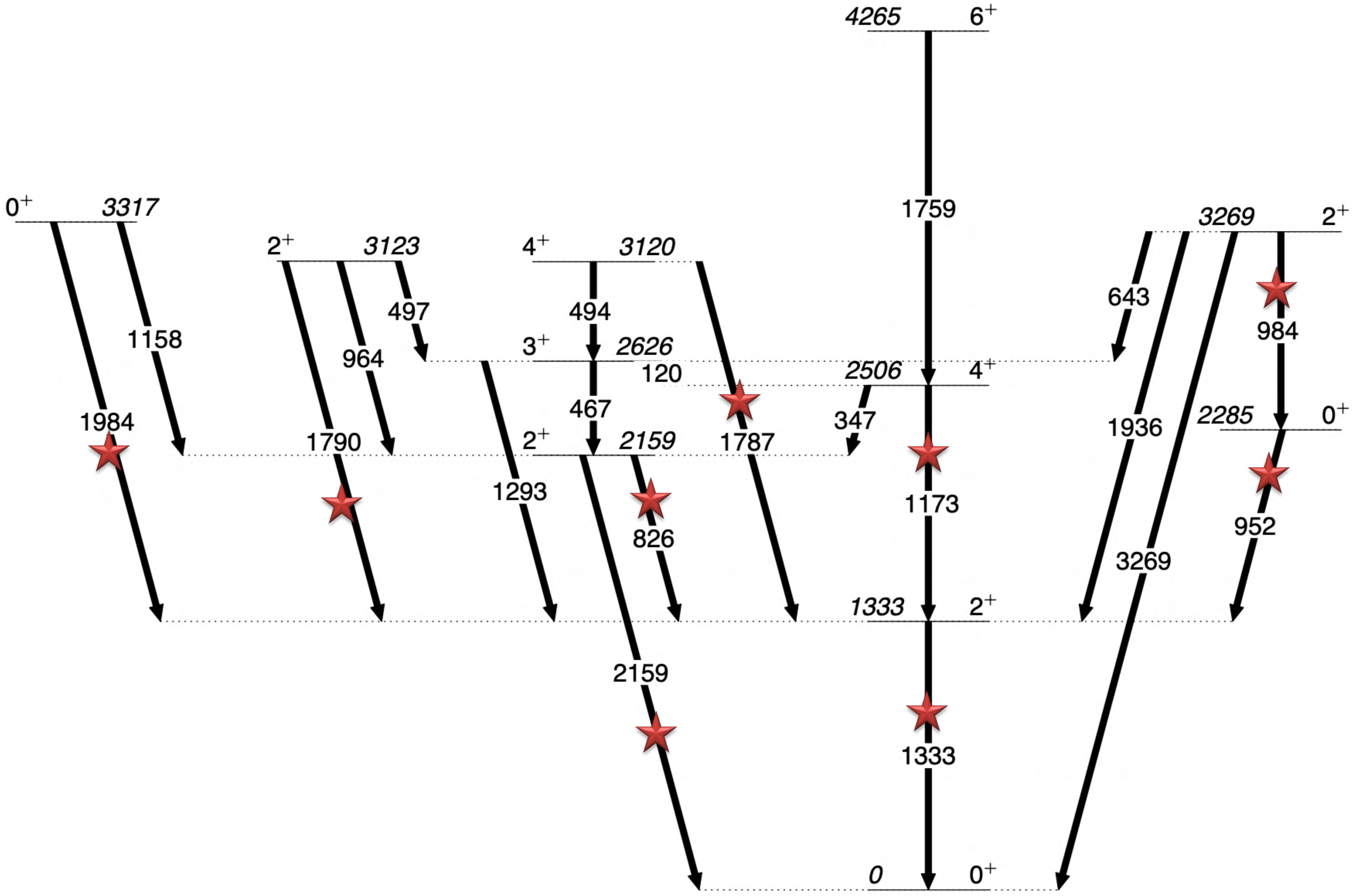
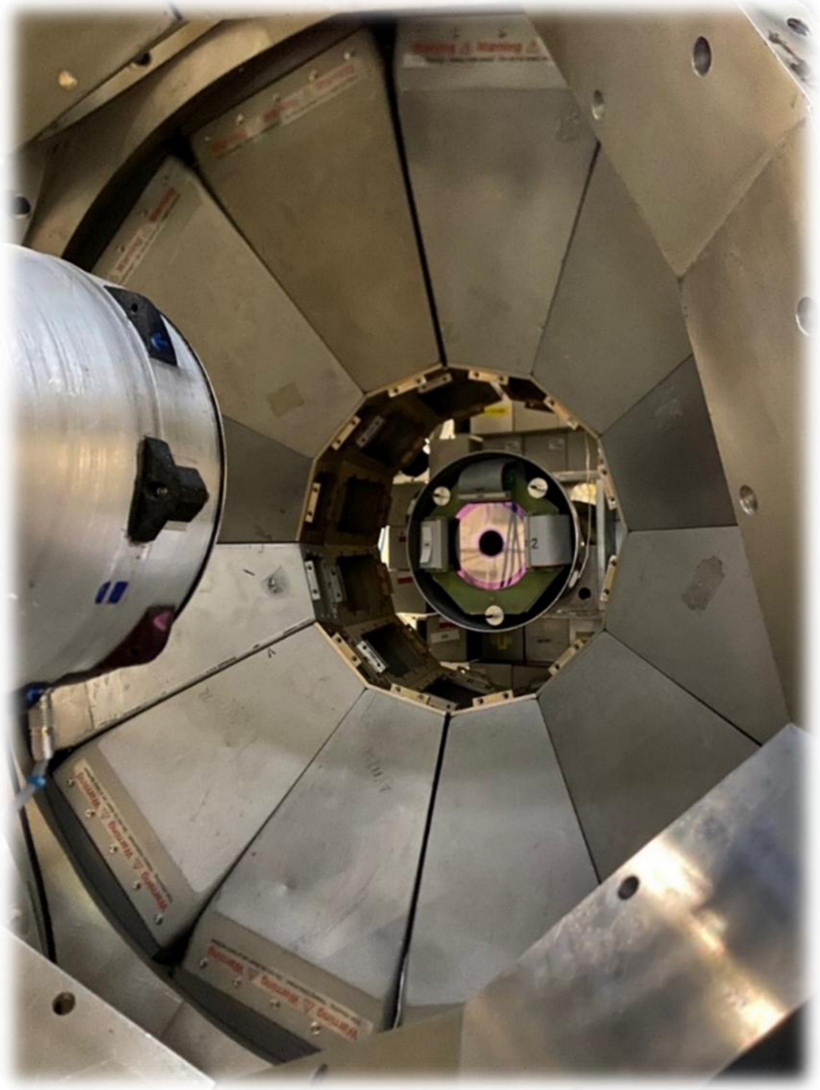


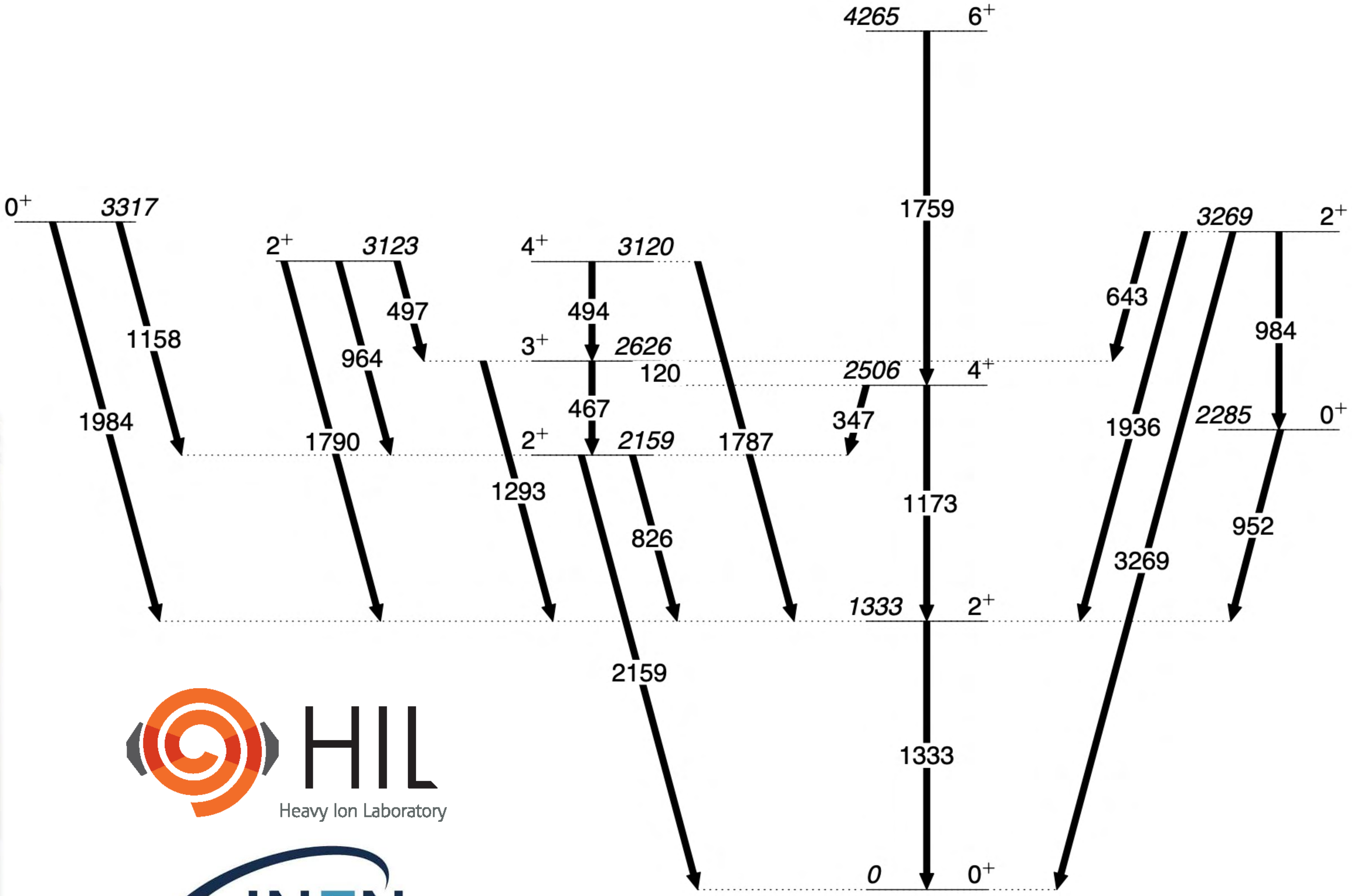


Analysis is ongoing
Agata Krzysiek (Faculty of Physics, UW),
master thesis

^{60}Ni – IJC Lab, Orsay (2023) – when ^{62}Ni was impssible

- ^{62}Ni -> ^{60}Ni beam, 233 MeV, 1 pnA
- ^{208}Pb -> ^{197}Au target, 2 mg/cm^2
- 7 days of data taking
- HIL Warsaw SilCA DSSD (127-154^o) + NUBALL2

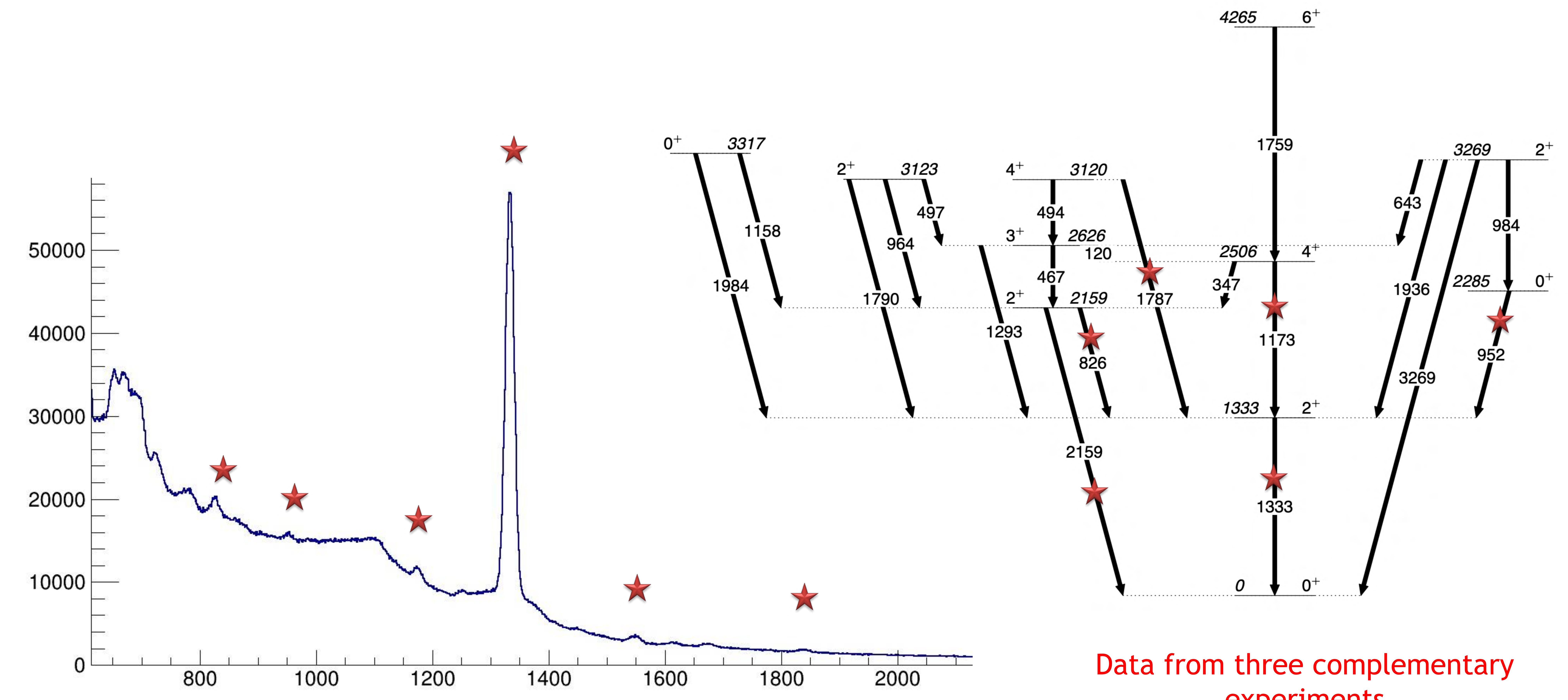




Heavy Ion Laboratory

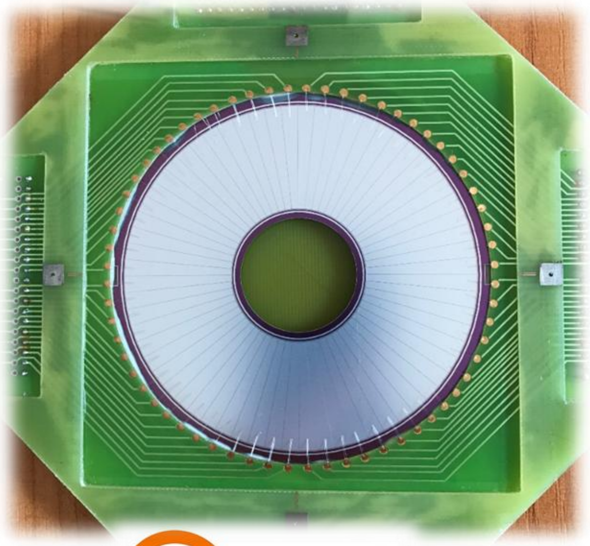
Istituto Nazionale di Fisica Nucleare
Sezione di Firenze

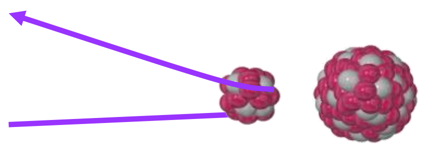
^{60}Ni – IJC Lab, Orsay (2023) – when ^{62}Ni was impssible

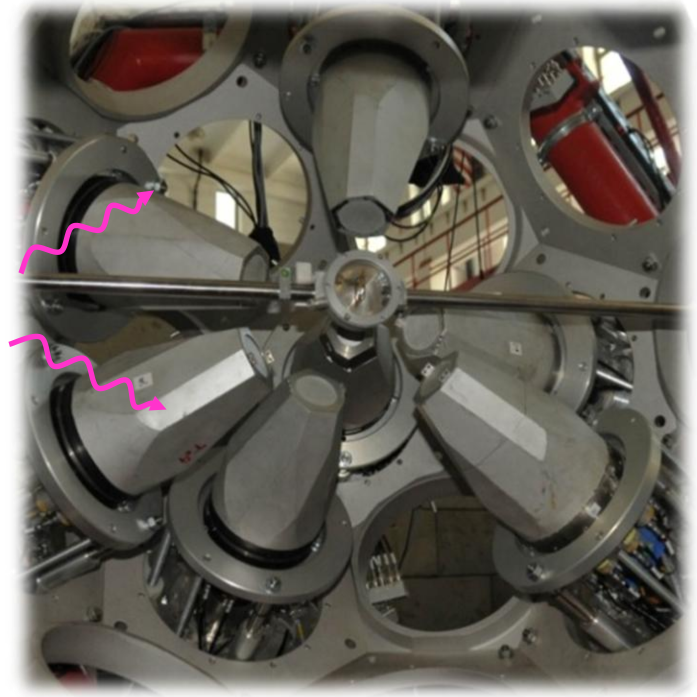


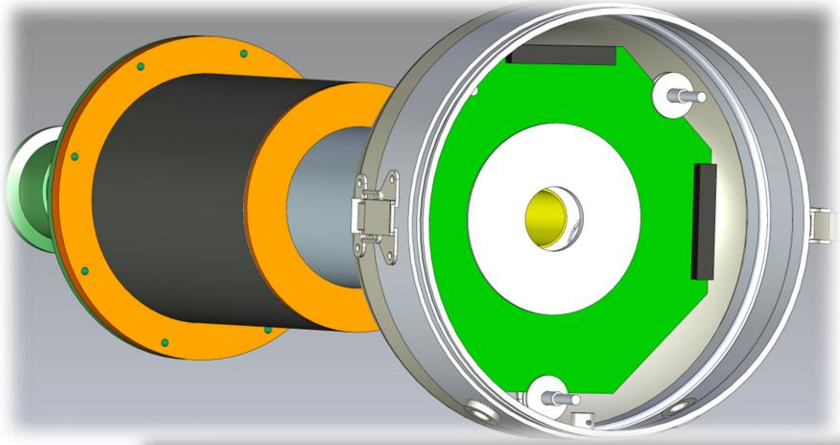
Data from three complementary experiments

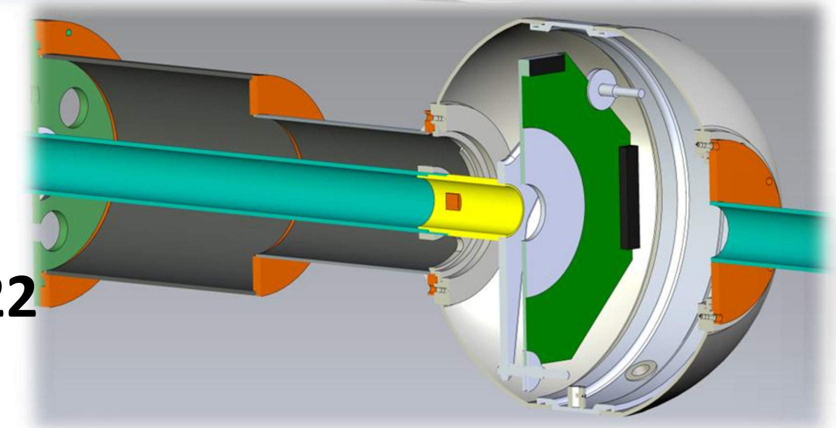
SilCA – Silicon Coulex Array







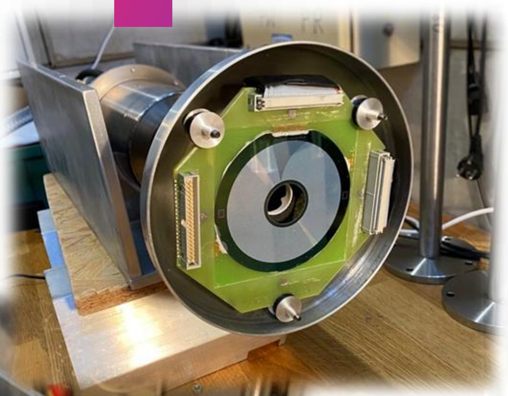




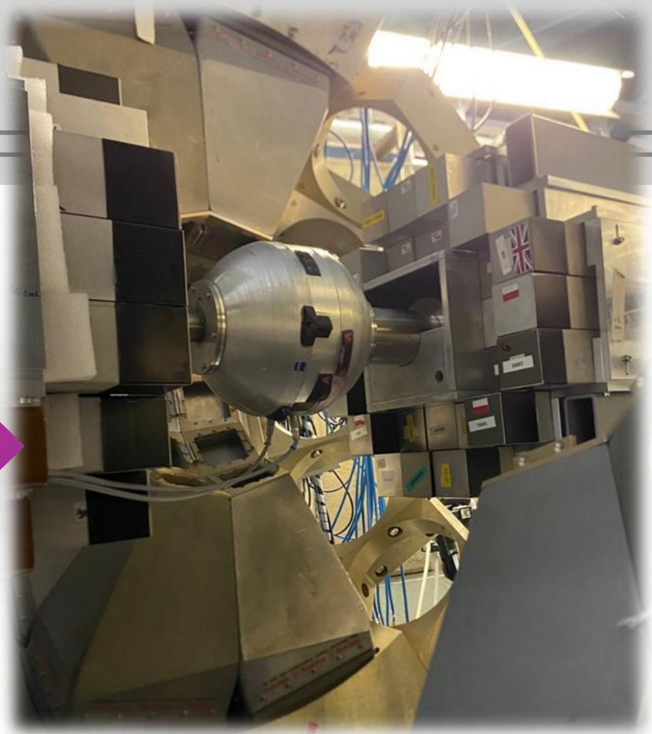
- r_{in} = 1.6 cm
- r_{out} = 4.2 cm
- 64 sectors (32 readout)
- 32 rings (16 readout)

Spring 2022

October 2022

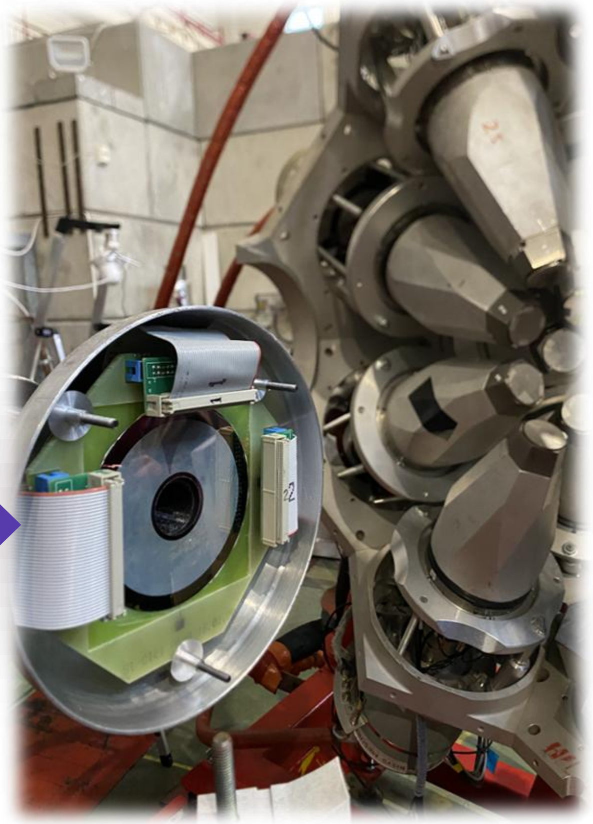


Commisioning in December 2022



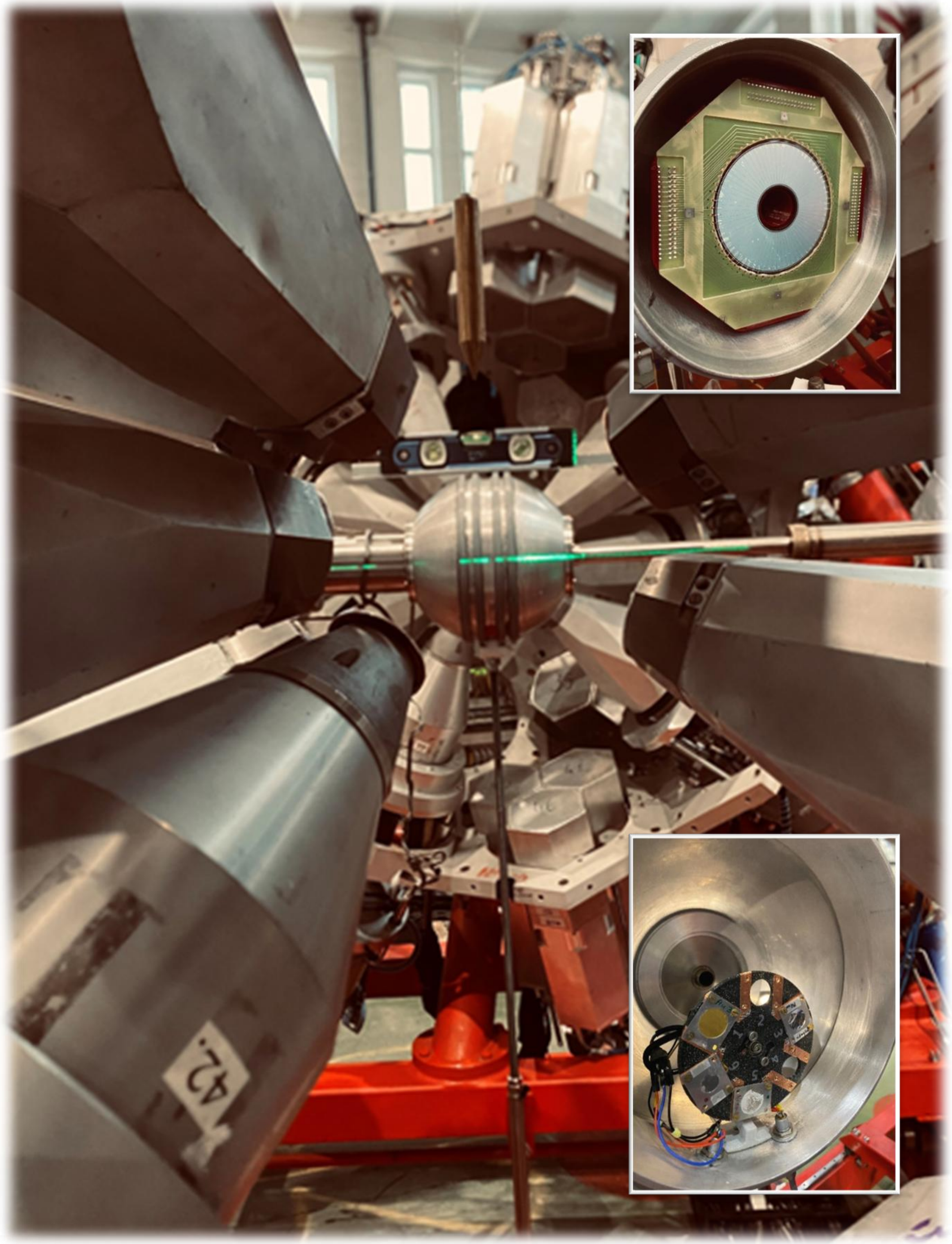
Campaign
DSSD+NuBALL2
(+PARIS)
I-VI 2023
7 experiments
Fully digital, FASTER

Sent to University of Lund for the re-bonding and annealling



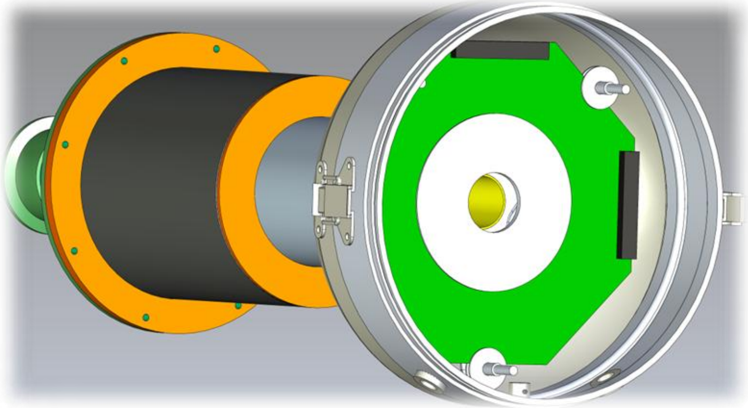
Project: P. Napiorkowski, J. Iwanicki, A. Iwanicki, J. Mierzejewski, KHK

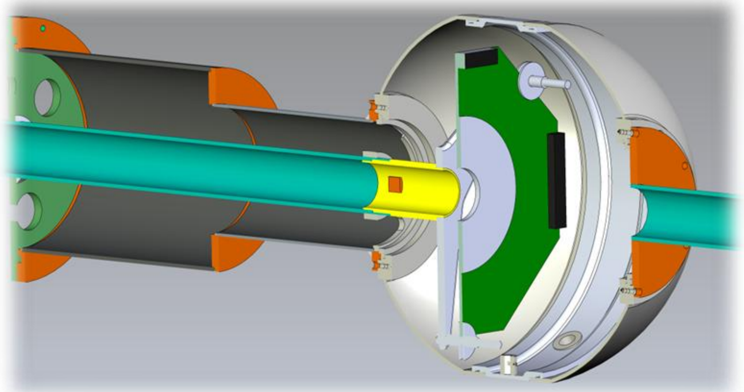
SilCA – Silicon Coulex Array

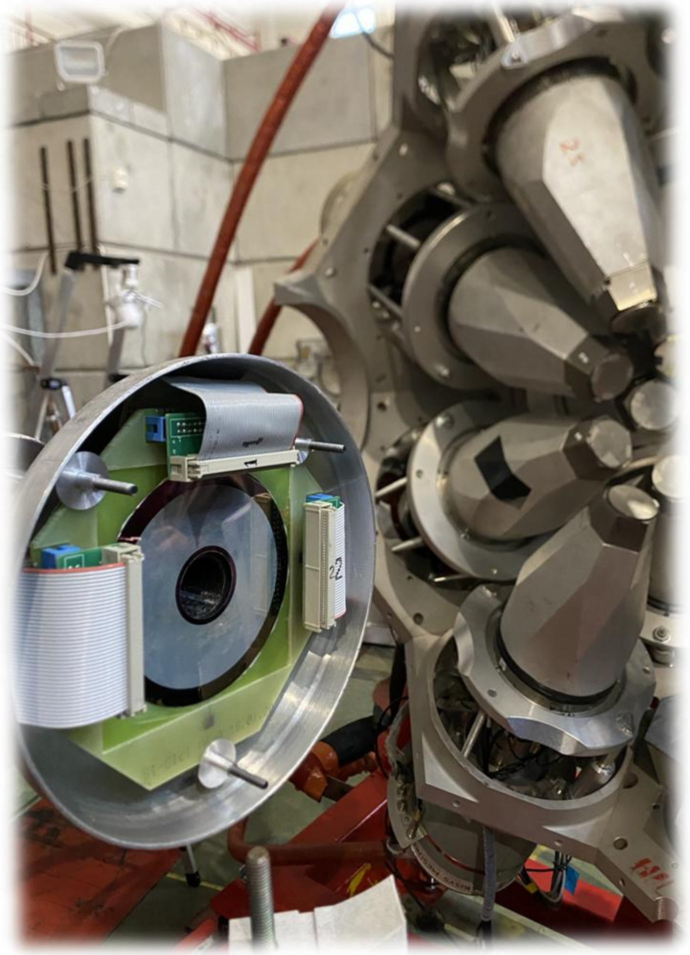


- DSSD array, circular type:
  - r_{in} = *1.6 cm*
  - r_{out} = *4.2 cm*
  - *64 sectors (32 readout channels)*
  - *32 rings (16 readout channels)*
- Designed and built at HIL Warsaw in 2022
- Commissioned in-beam at IJC Lab in December 2022 – followed by the campaign DSSD+NUBALL2+PARIS
- **Commissioned in-beam at HIL in November 2024 (Coulomb excitation reaction)**
- Possible angular ranges at various distances from the target:
  - ➢3 cm: 125 – 150°
  - ➢3.5 cm: 129 – 154°
  - ➢4 cm: 133 – 157°

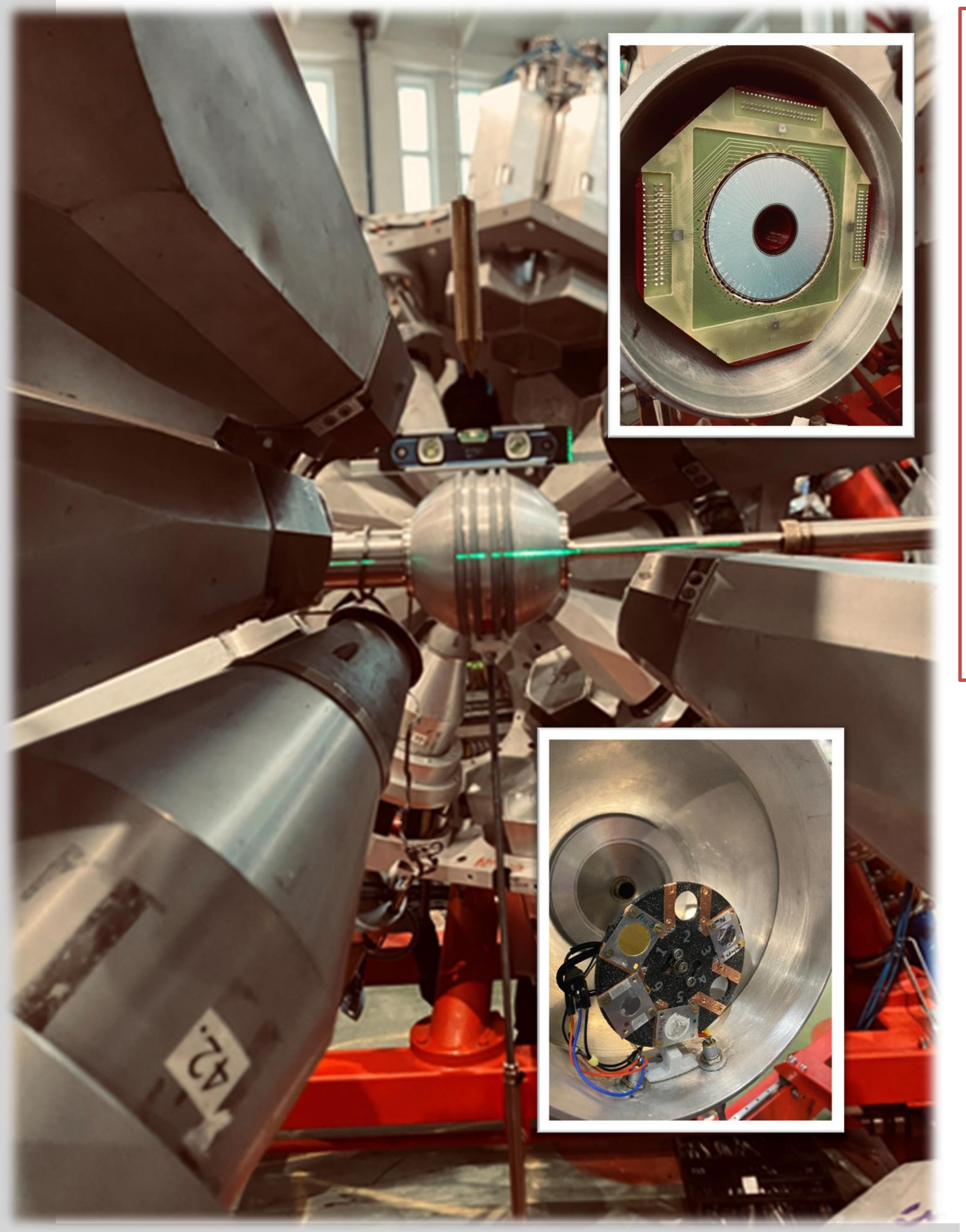
UNIVERSITY OF WARSAW
Heavy Ion Laboratory
HIL



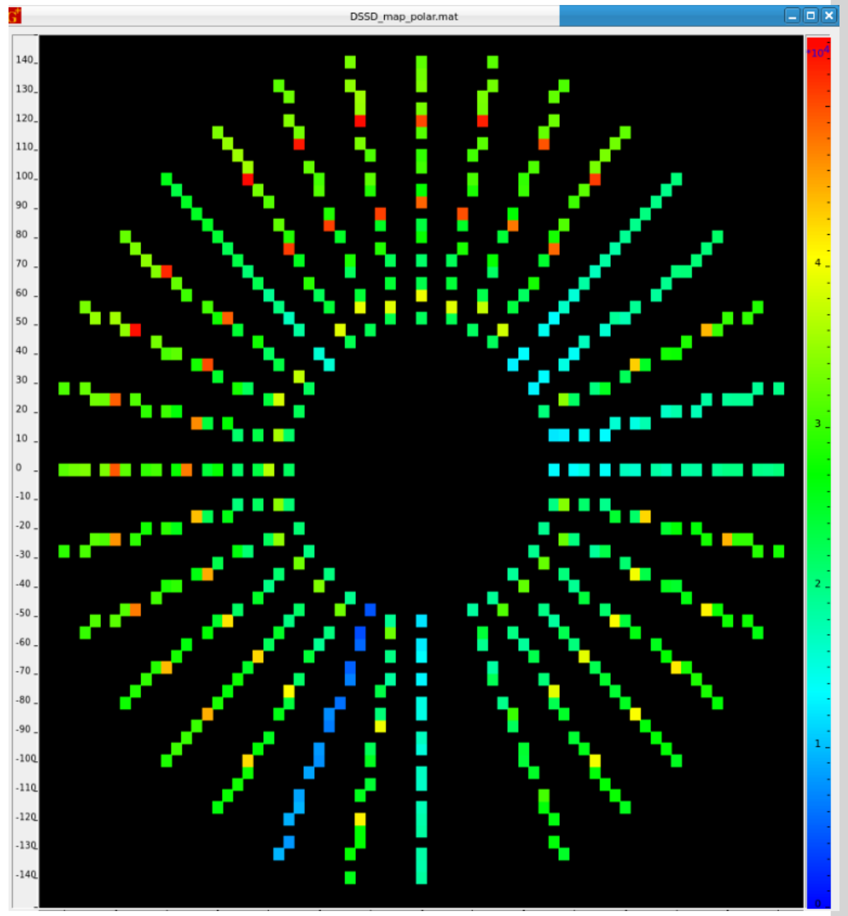


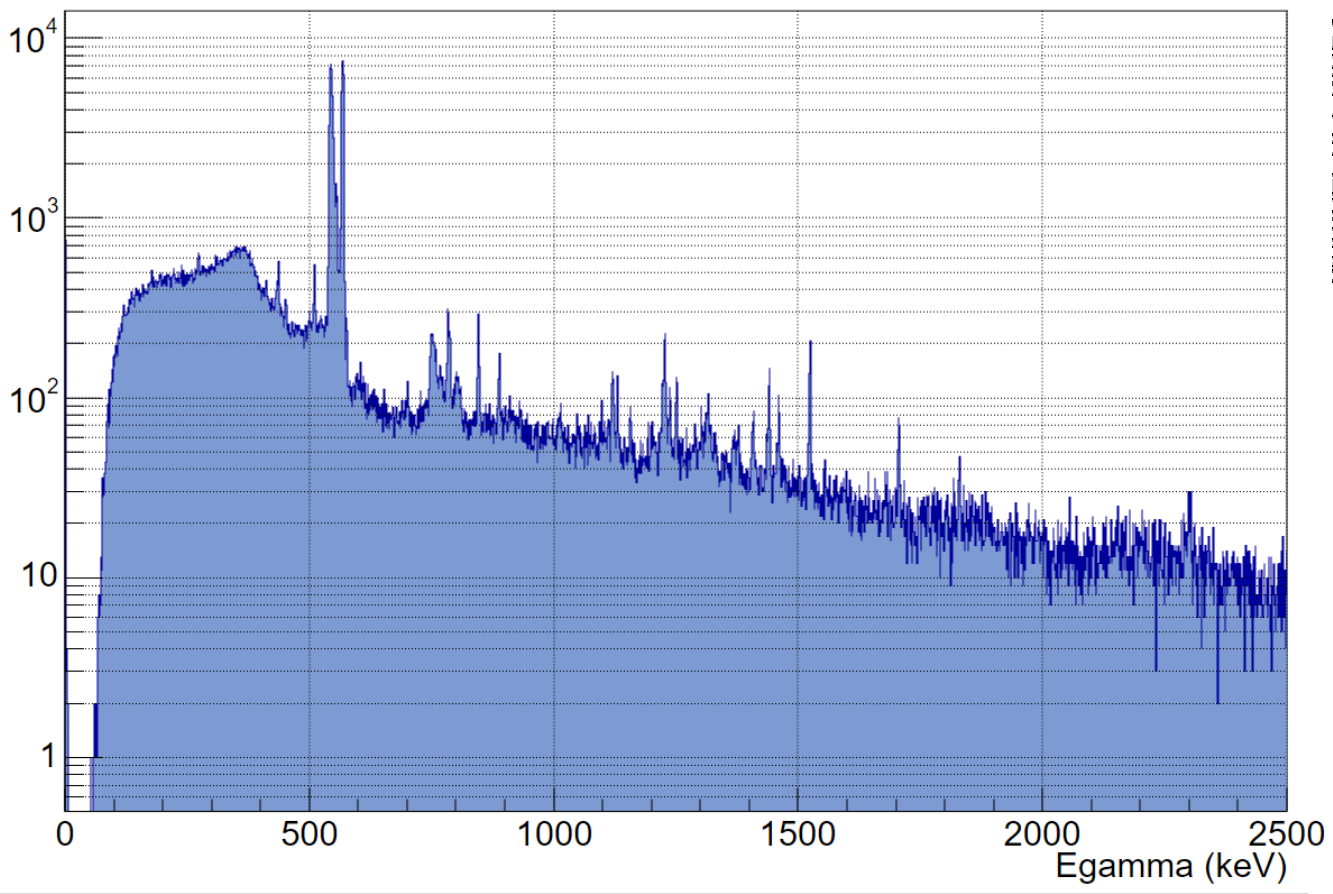


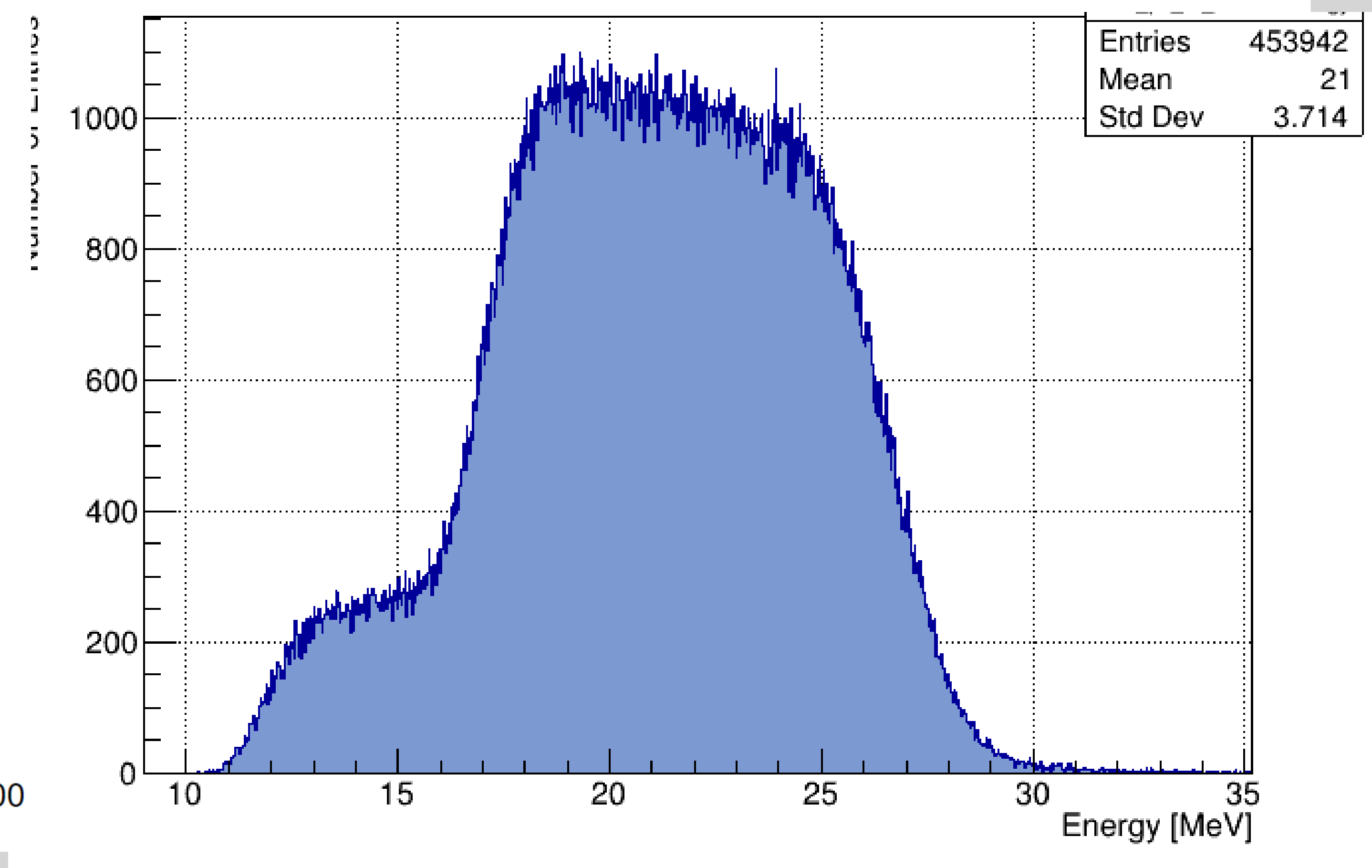
SilCA @ HIL (November 2024) – Coulomb excitation of ^{104}Pd



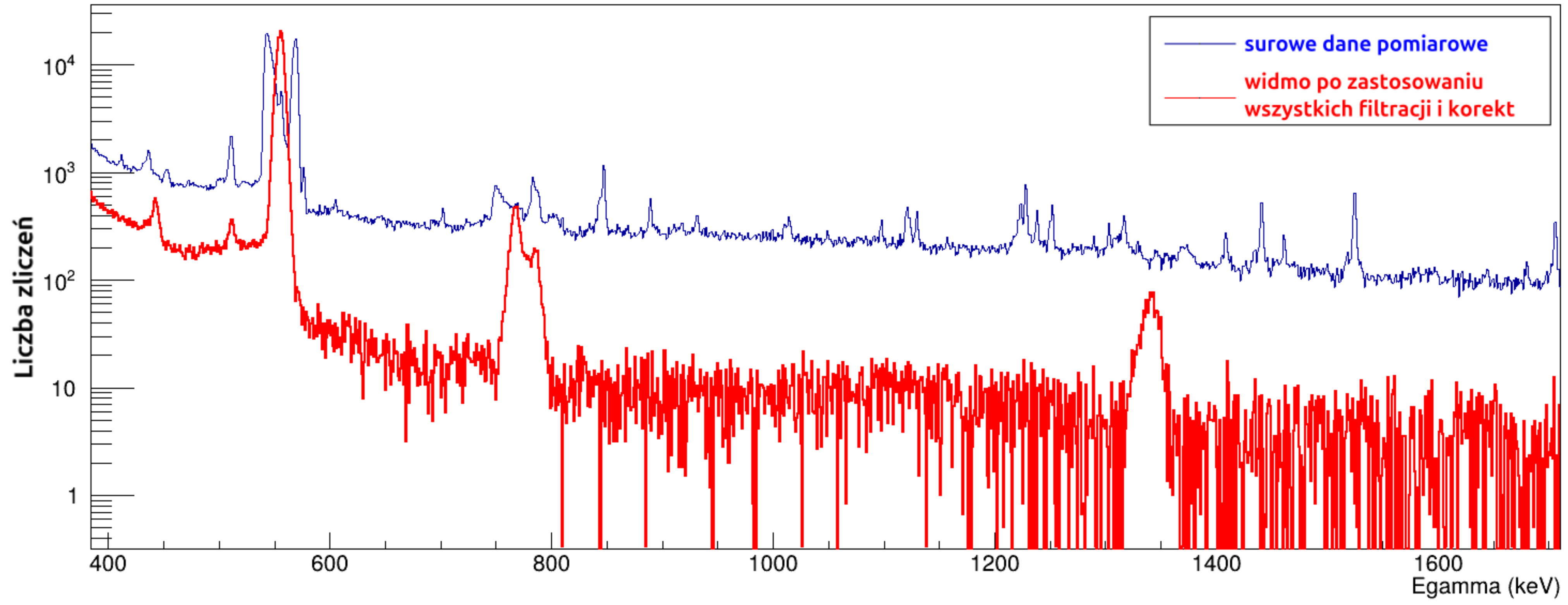
- ^{32}S beam, 90 MeV, 1-2 pnA
- ^{104}Pd (+ natBa and ^{197}Au targets), 1 mg/cm^2 each - on the automatic taget wheel, 6 spots, camera inside
- 4 days (12-15 Nov 2024)
- 13 HPGe (11 GAMMMAPOOL + 2 smaller)
- SiLCA DSSD – 133-157^o, 4cm from the target
- 31/32 sectors and 16/16 rings were working
- Total dark current increased from 16 to 22 uA
- CAEN 1725 digitizers – 2 for HPGe + ACS, 3 for DSSD, 1 for NEDA + trigger
- AGAVA for the GTS
- XDAQ (LNL upgrade CERN-based DAQ), particle hardware trigger
- GREWARE + SPY – online visualisation (J. Grębosz, IFJ PAN Krakow)

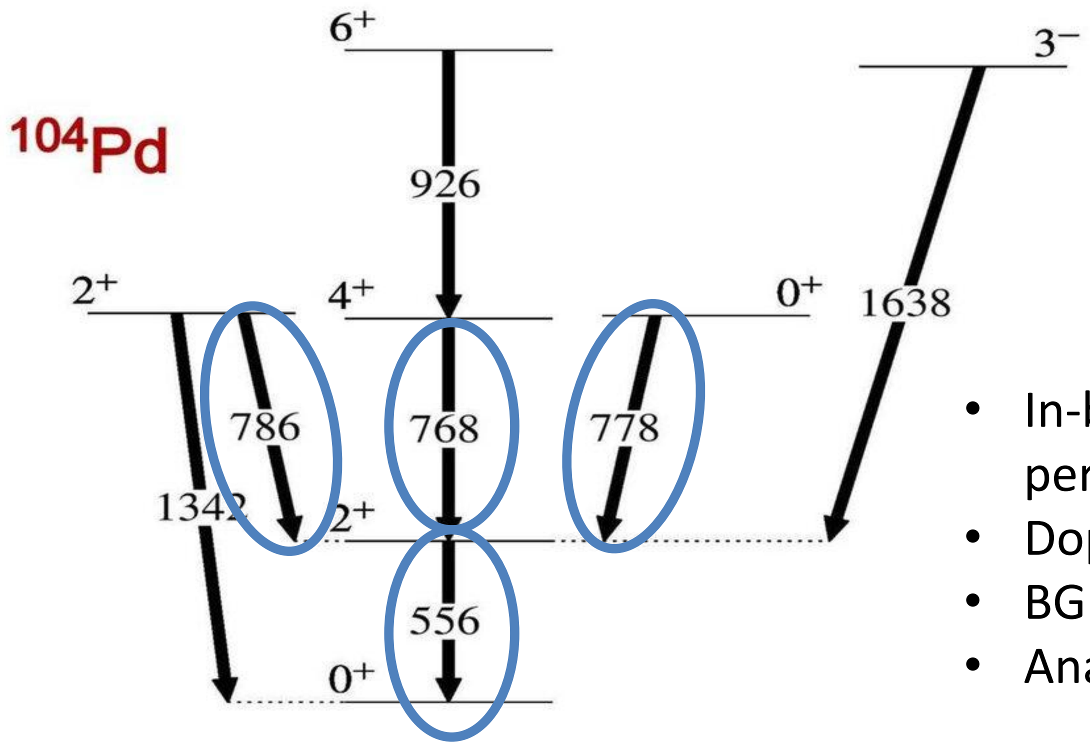


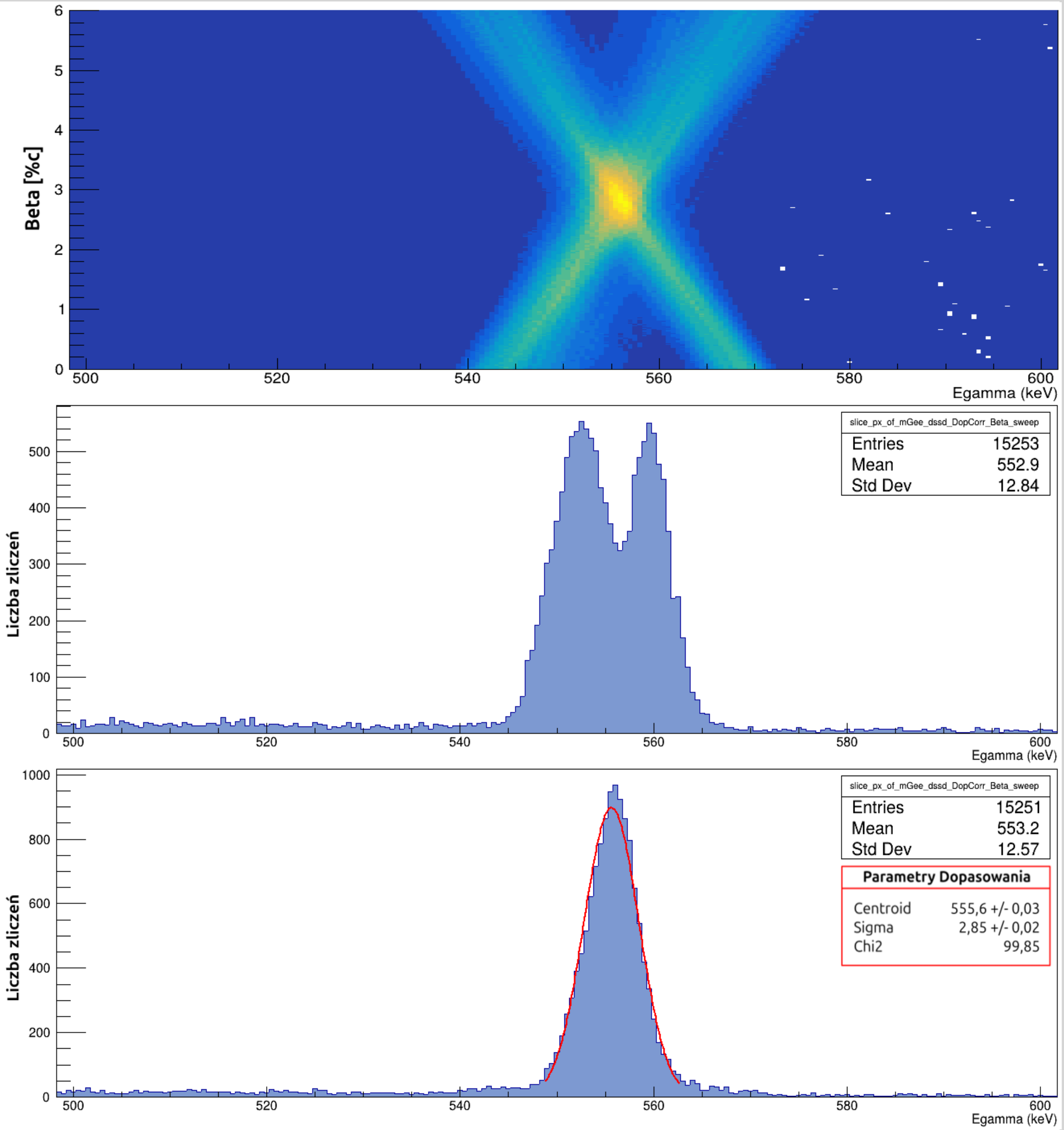




SilCA @ HIL (November 2024) – Coulomb excitation of ^{104}Pd







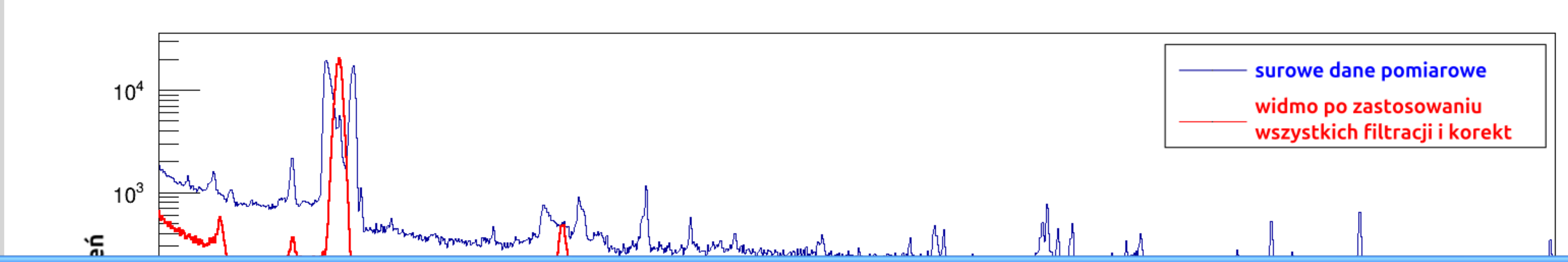
- In-beam test at HIL – DSSD was performing well – excellent perspective for the future projects
- Doppler Correction – mean beta done
- BGR subtraction: based on the particle spectra + time
- Analysis ongoing – event-by-event DC in delivery

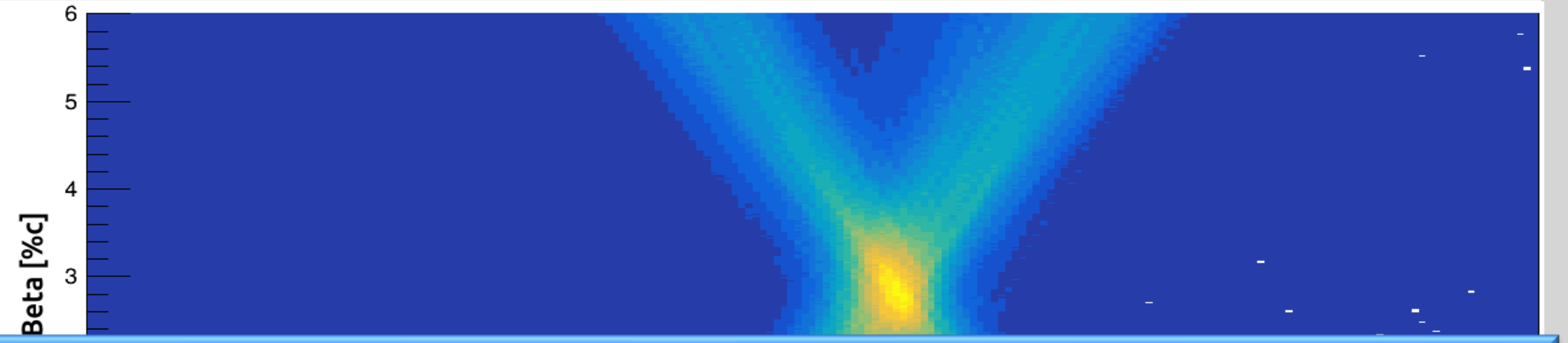
BSc thesis of Grześ Szymanek (FUW)

Thanks to (in alphabetical order):

P. Dei, J. Grębosz, C. Hiver, G. Jaworski, M. Komorowska, M. Kowalczyk, A. Krzysiek, A. Malinowski, M. Matuszewski, J. Mierzejewski, P. Napiorkowski, M. Palacz, S. Panasenko, I. Piętka, J. Samorajczyk-Pyśk, P. Sekrecka, K. Solak, A. Spacek, G. Szymanek, K. Wrzosek-Lipska + the target lab (A. Stolarz, J. Kowalska)

SilCA @ HIL (November 2024) – Coulomb excitation of ^{104}Pd





<u>Accepted Coulomb excitation proposals:</u>

- ^{40}Ar (KHK, M. Rocchini (INFN Firenze, Italy), N. Marchini) (INFN Firenze, Italy)
- ^{62}Ni (KHK, M. Rocchini (INFN Firenze, Italy), N. Marchini (INFN Firenze, Italy))
- ^{34}S (J. Heery (Uni of Surrey, UK), J. Henderson (Uni of Surrey, UK), KHK)
- ^{122}Te (D. Kalaydjieva (Uni of Guelph, Canada), M. Siciliano (ANL, USA))
- ^{136}Ba (B. Lenardo (SLAC National Accelerator Laboratory, USA) , M. Scheck (University of the West of Scotland, UK) , Smarajit Triambak (University of Western Cape, SA)),
- ^{232}Th (W. Korten (CEA Saclay))
- ^{100}Ru (P.E. Garrett (Uni of Guelph, Canada), M. Rocchini (INFN Firenze, Italy), K. Wrzosek-Lipska (HIL Warsaw), M. Zielińska (CEA Saclay))

Thanks to (in alphabetical order):

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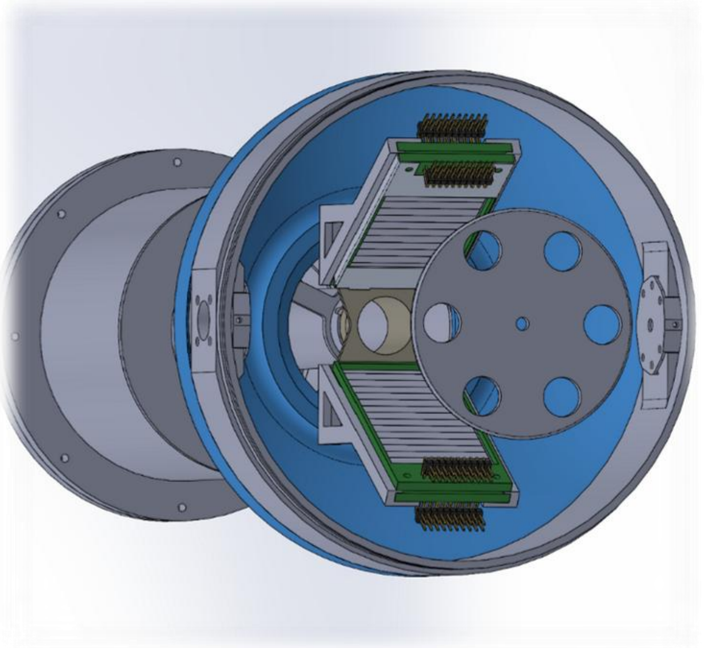
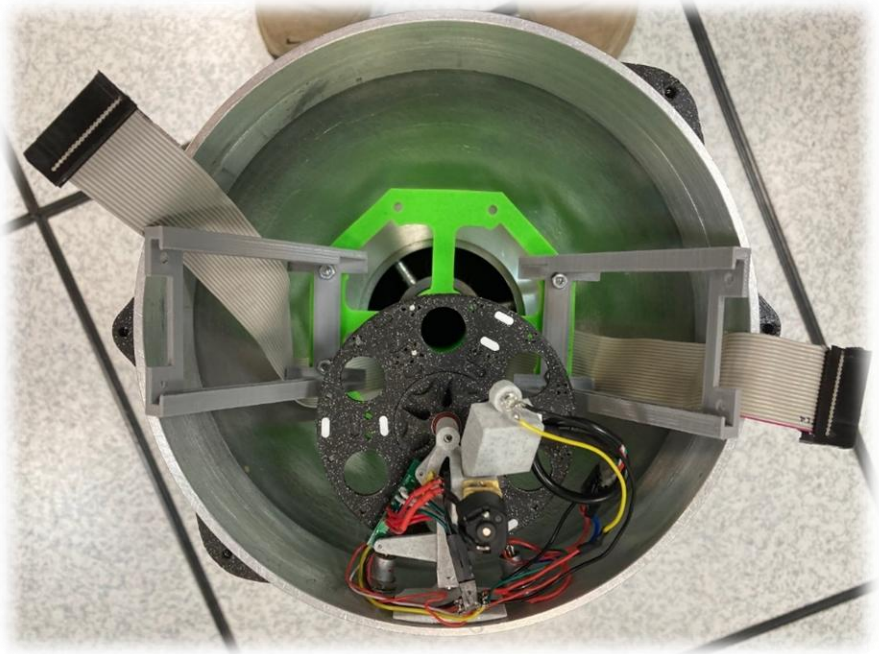
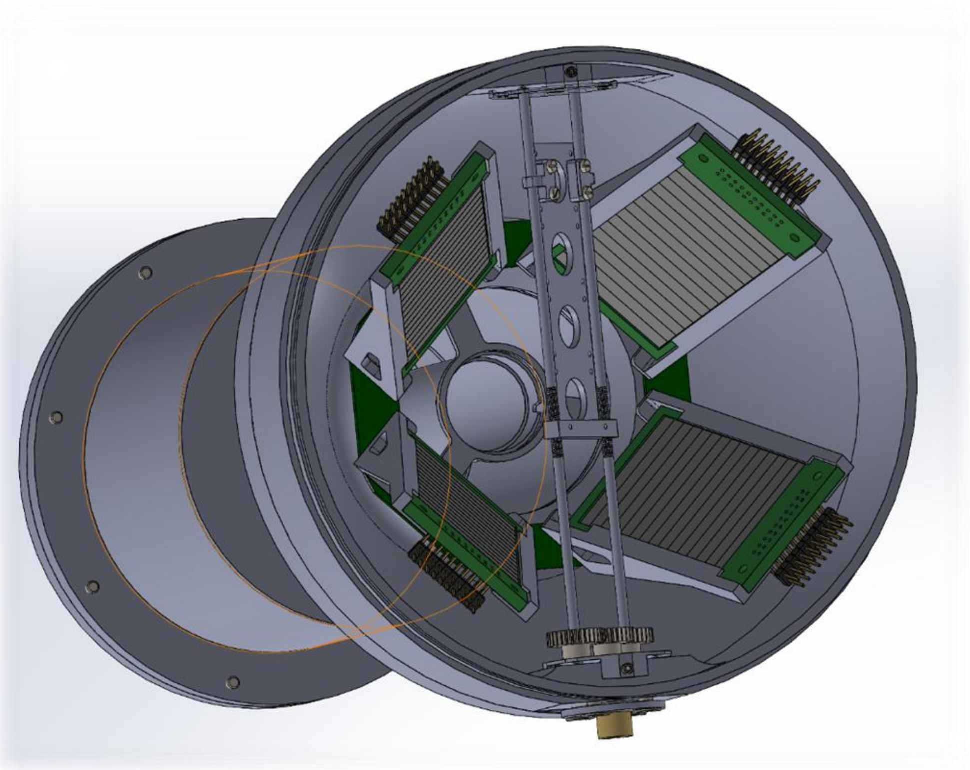
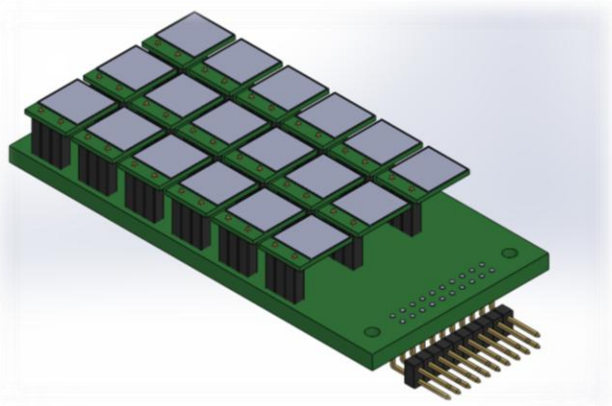
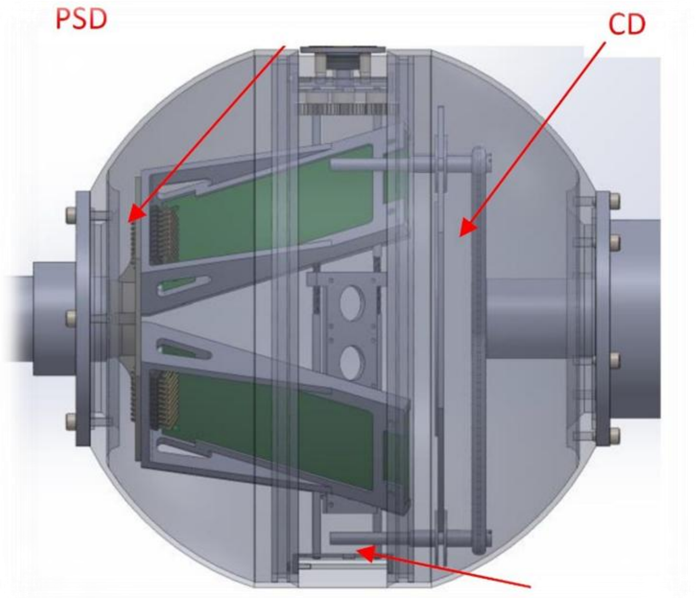
SilCA and beyond!











- Position-sensitive DSSD detectors (Micron X3, 43.3 × 78 mm) E or E-dE
- A set of pin-diodes
- Scintilators

To-do list

- Coulex of ^{40}Ar – HIL Warsaw, accepted, to be scheduled in 2025
- Coulex of ^{62}Ni (target) – HIL Warsaw – accepted, to be scheduled in 2025
- Coulex of ^{44}Ca – INFN LNL – accepted, to be scheduled in …

- Coulex of ^{62}Ni (beam) – INFN LNL / ANL – to be proposed
- Coulex of ^{56}Ni – GANIL – to be proposed
- Coulex of ^{40}Ca – INFN LNL – to be proposed when PARIS is at LNL
- Coulex of ^{36,38}Ar – INFN LNL – LOI accepted, to be submitted when PARIS is at LNL

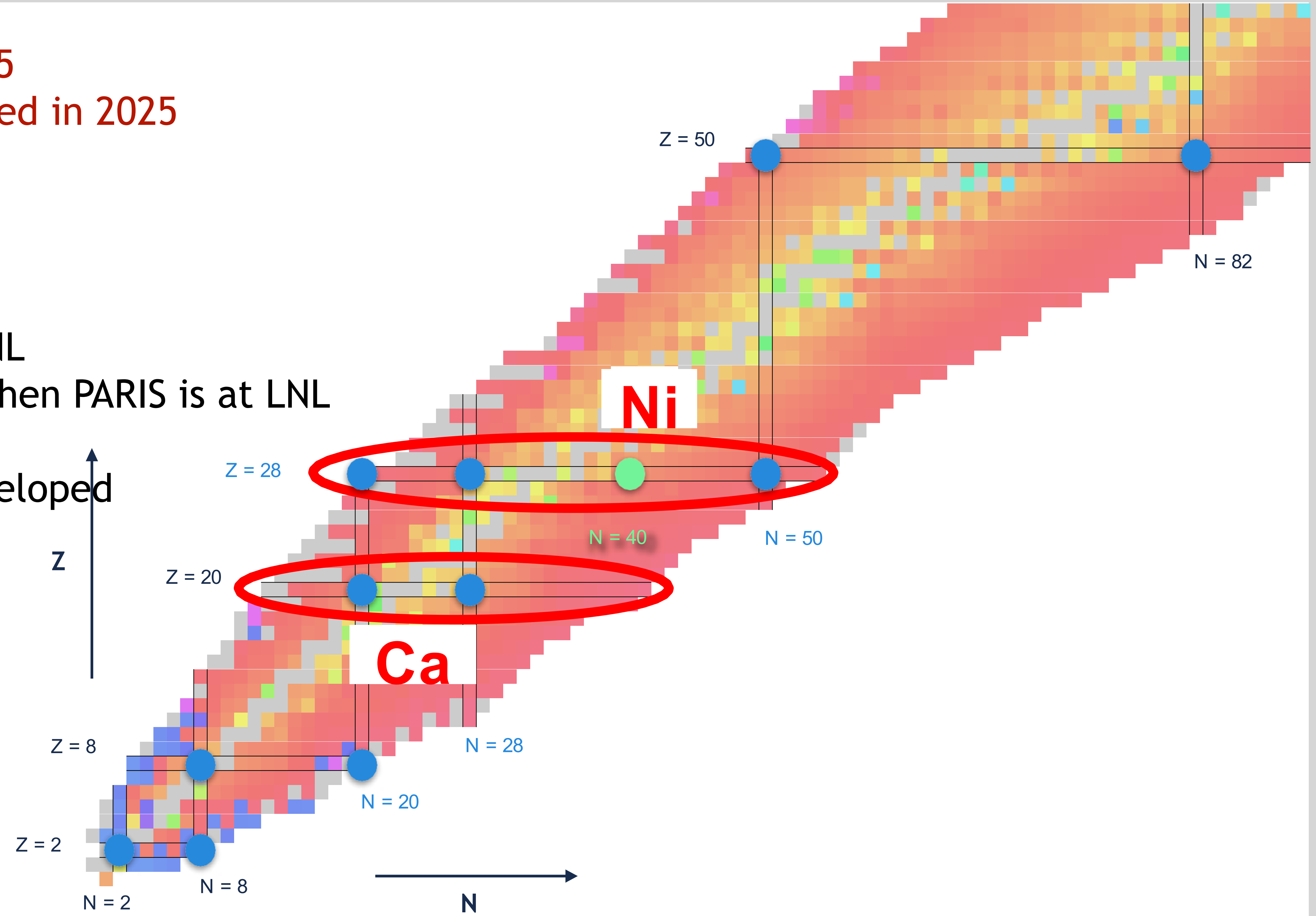
- Coulex of ^{62}Zn – GANIL – to be proposed when the beam is developed
- Coulex of ^{44}Ti – IJC Lab / GANIIL – LOI endorsed
- Lifetimes in ^{42}Ca, ^{44}Ti – HIL Warsaw – to be proposed

Collected data:

- ✓ Coulex of ^{60}Ni (INFN LNL, IJC Lab) – analysis ongoing
- ✓ Coulex of ^{58}Ni (INFN LNL) – analysis nearly done
- ✓ Coulex of ^{64}Zn (INFN LNL) – pending (manpower)

And…

- Theory and interpretation – ongoing



- **Open question: origin of the enhanced deformation?**
- **Properties of the magic and semi-magic shells?**
- **Is spherical REALLY spherical?**
- **STABLE nuclei – not so boring**

Quadrupole collectivity in ^{42}Ca from low-energy Coulomb excitation with AGATA

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^{40}Ca

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^{60}Ni

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^{62}Ni

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THANK YOU!!
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^{58}Ni

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