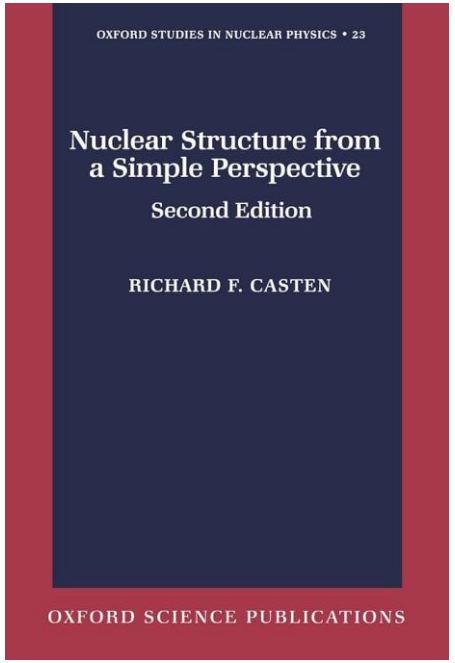
Quadrupole-octupole coupled states in ^{112}Cd via Coulomb excitation with AGATA and SPIDER

La Marca Tommaso

Scientific Motivation

Cd isotopes used as textbook examples of near harmonic vibrational nuclei

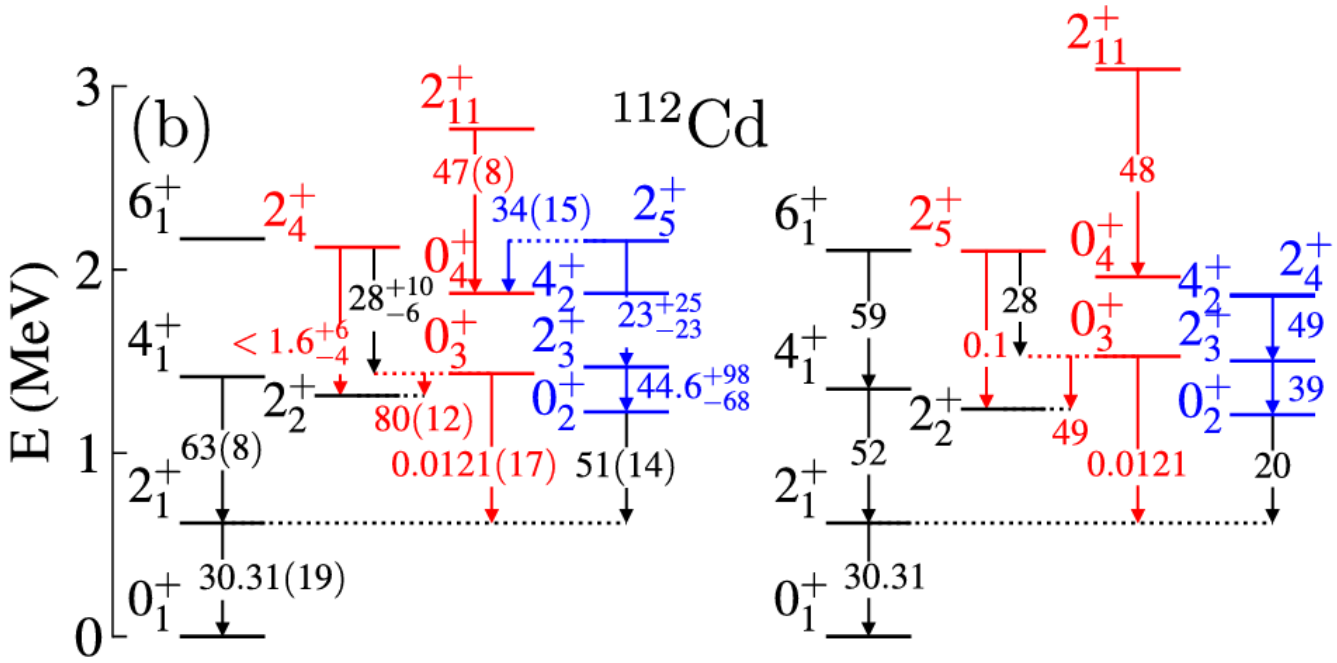


PHYSICAL REVIEW C **108**, L031305 (2023)

Letter

Persistent vibrational structure in $^{110-116}$Cd

N. Gavrielov,[1,2,*] J. E. García-Ramos,[3,†] P. Van Isacker,[4,‡] and A. Leviatan[2,§]



Scientific Motivation

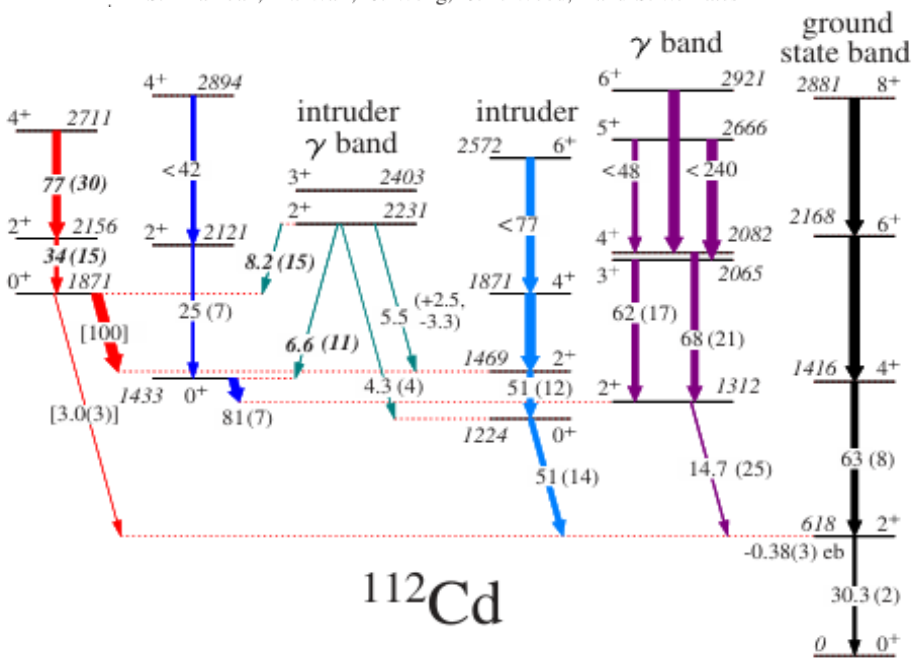
Recent results on ^{112}Cd interpreted as a rotational triaxial nucleus

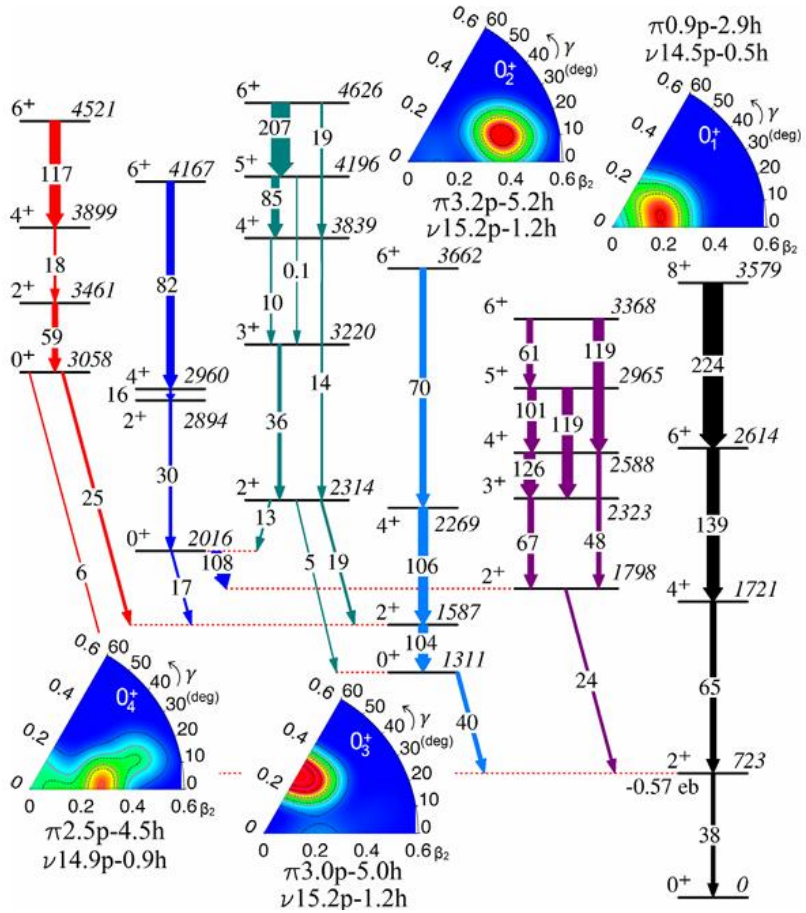
PHYSICAL REVIEW LETTERS **123,** 142502 (2019)

Editors' Suggestion | Featured in Physics

Multiple Shape Coexistence in ^{110,112}Cd

P. E. Garrett,[1,2] T. R. Rodríguez,[3] A. Diaz Varela,[1] K. L. Green,[1] J. Bangay,[1] A. Finlay,[1] R. A. E. Austin,[4] G. C. Ball,[5] D. S. Bandyopadhyay,[1] V. Bildstein,[1] S. Colosimo,[4] D. S. Cross,[6] G. A. Demand,[1] P. Finlay,[1] A. B. Garnsworthy,[5] G. F. Grinyer,[7] G. Hackman,[5] B. Jigmeddorj,[1] J. Jolie,[8] W. D. Kulp,[9] K. G. Leach,[1,*] A. C. Morton,[5,†] J. N. Orce,[2] C. J. Pearson,[5] A. A. Phillips,[1] A. J. Radich,[1] E. T. Rand,[1,‡] M. A. Schumaker,[1] C. E. Svensson,[1] C. Sumithrarachchi,[1,†] S. Triambak,[2] N. Warr,[8] J. Wong,[1] J. L. Wood,[10] and S. W. Yates[11]

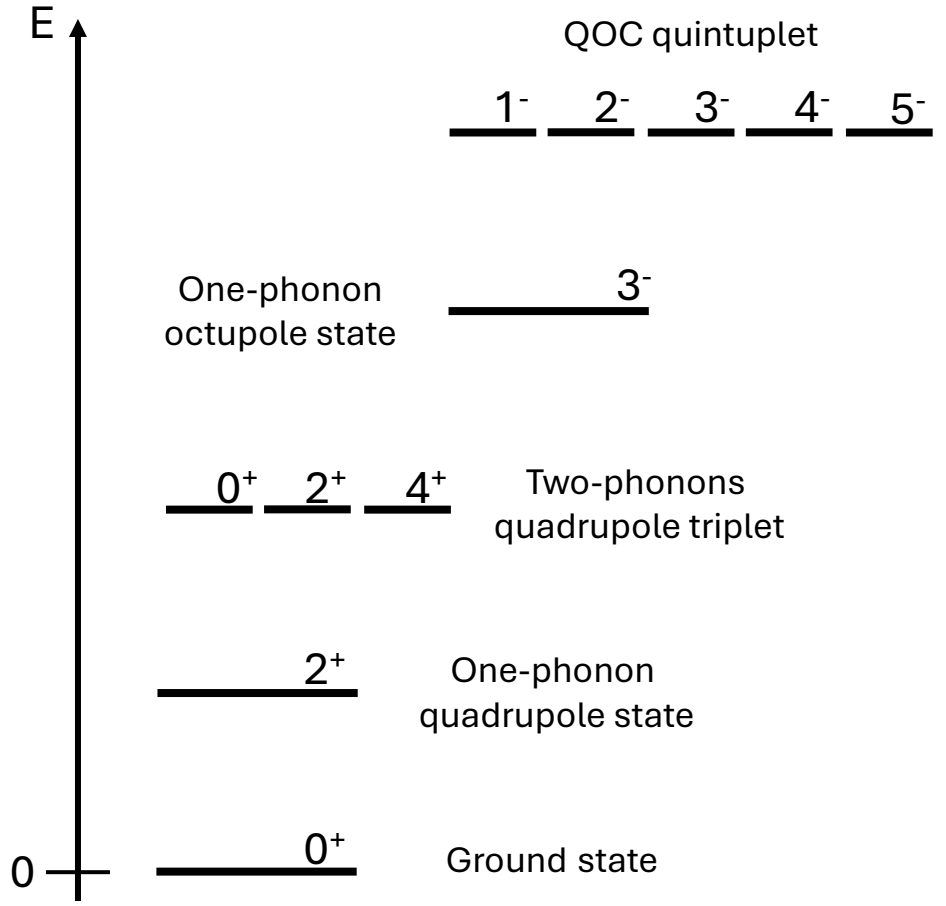




Scientific Motivation

Quadrupole – Octupole Coupled states

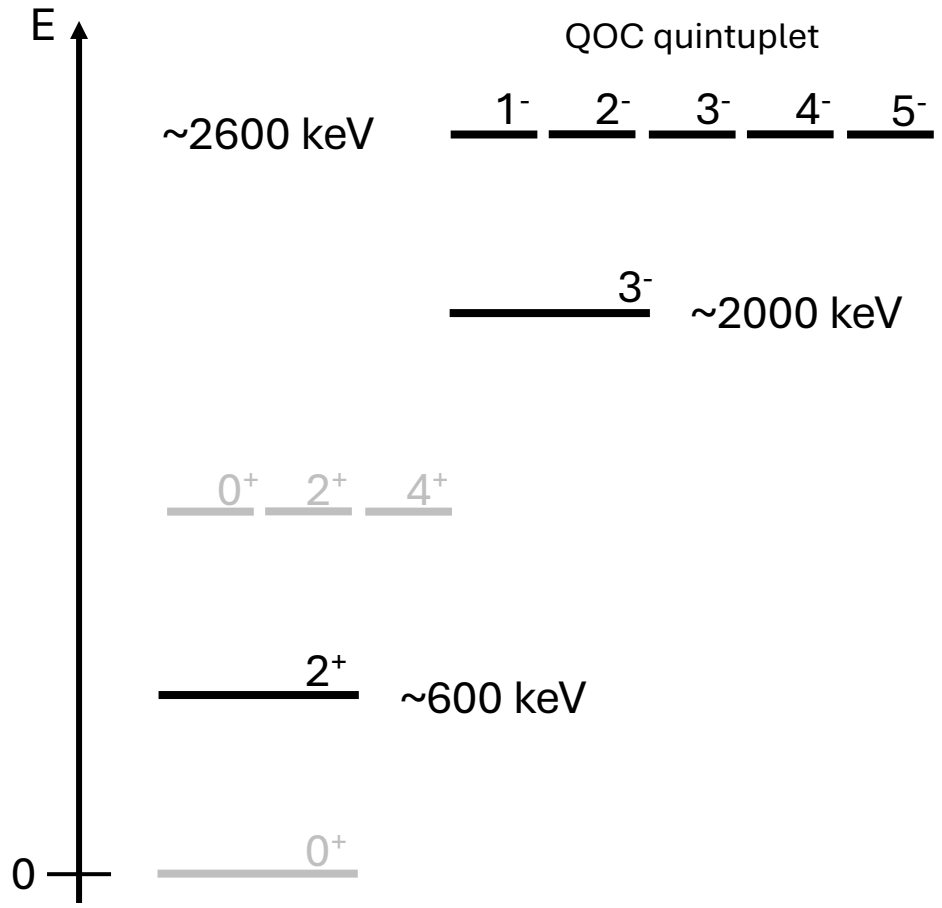
- In the vibrational picture, the interaction of quadrupole and octupole phonons creates the QOC quintuplet of states
- Marginal differences in vibrational and rotational features of positive parity states at low energy
- More marked differences in negative parity states



Scientific Motivation

Ideal properties of QOC states

- QOC states' energy at about the sum of single quadrupole and octupole phonons
- 1^-_{QOC} state characterised by a strong E1 transition to the ground state
- B(E2;QOCs $\longrightarrow 3_1^-$) of the same magnitude of B(E2;$2_1^+ \longrightarrow 0_1^+$)
- B(E3;QOCs $\longrightarrow 2_1^+$) of the same magnitude of B(E3;$3_1^- \longrightarrow 0_1^+$)



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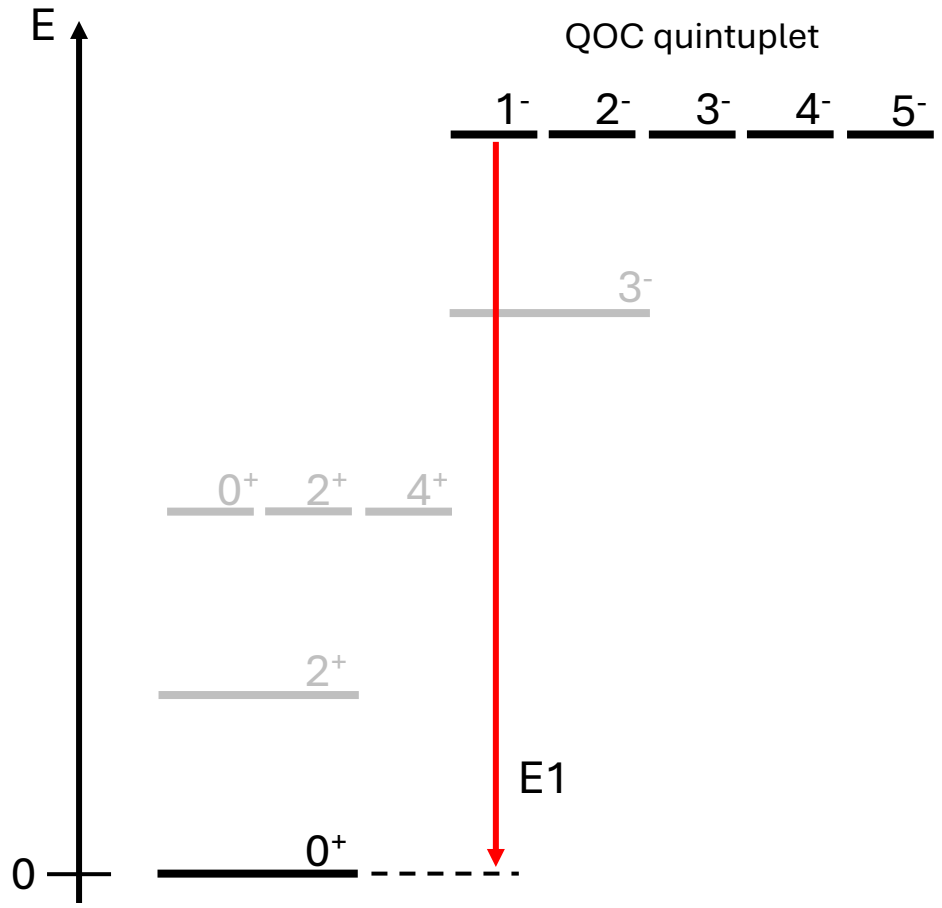

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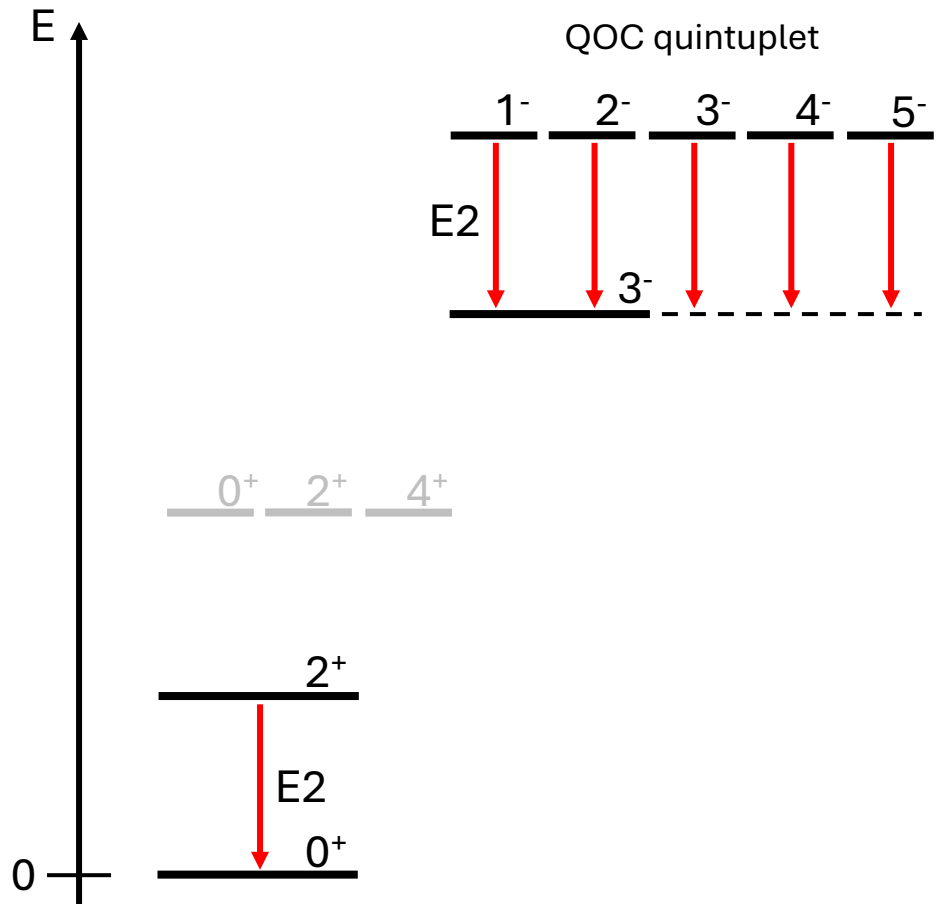

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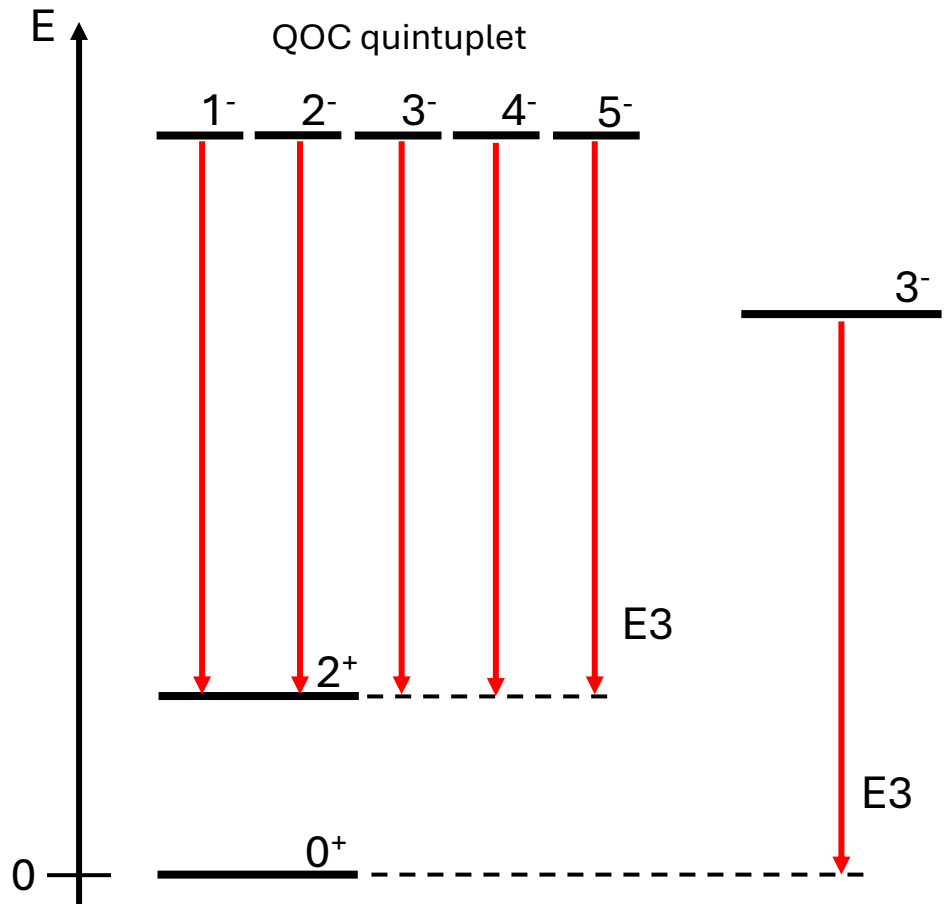


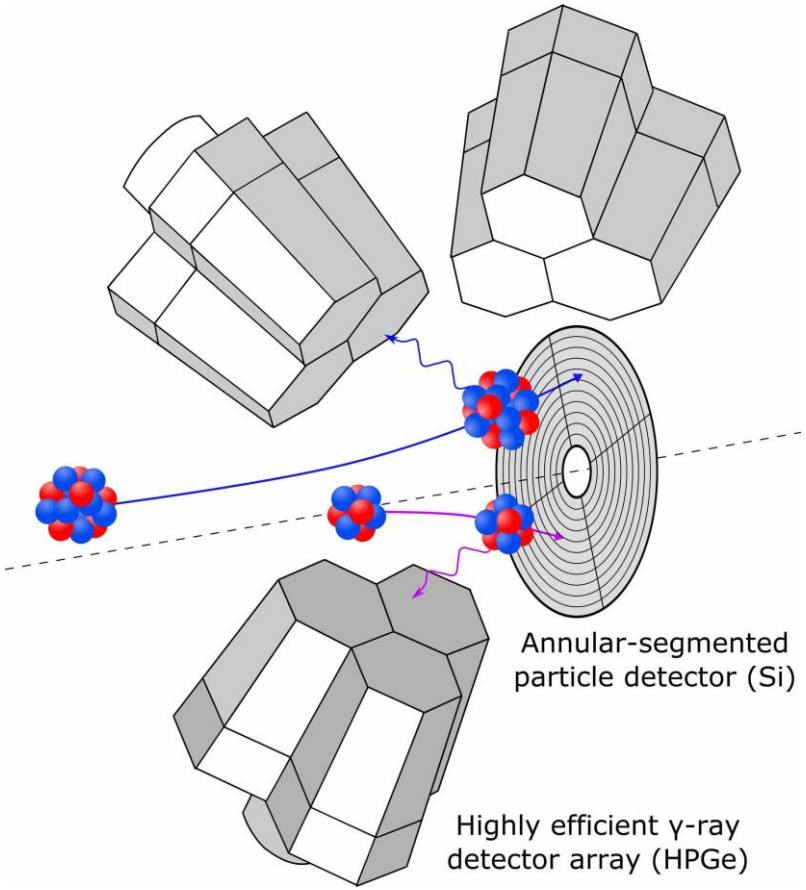
Experimental Technique

Coulomb excitation of ^{112}Cd

- Inelastic electromagnetic scattering
- Allows for model independent measurements of important observables
- ^{60}Ni beam @ 187 MeV on ^{112}Cd target

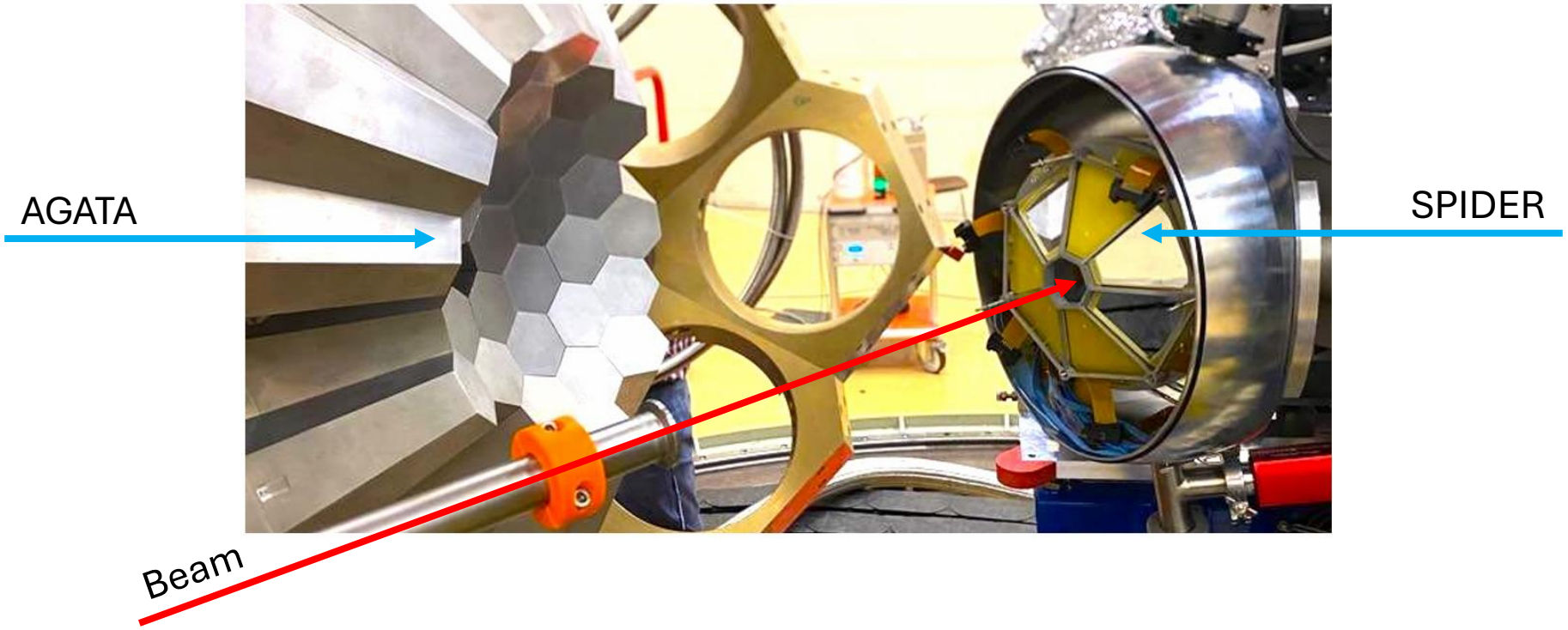
$$D_{min} = R_p + R_t + \Delta \approx 1.2\left(A_p^{1/3} + A_t^{1/3}\right) + 5\ [fm]$$

$$\sigma_{coulex} \propto P(I_i \rightarrow I_f)\left[1 + K(\theta)Q(I_f)\right]$$



Experimental Apparatus

- Coulomb excitation of ^{112}Cd
- Setup: AGATA + SPIDER at Laboratori Nazionali di Legnaro (LNL-INFN, Italia)



Experimental Apparatus

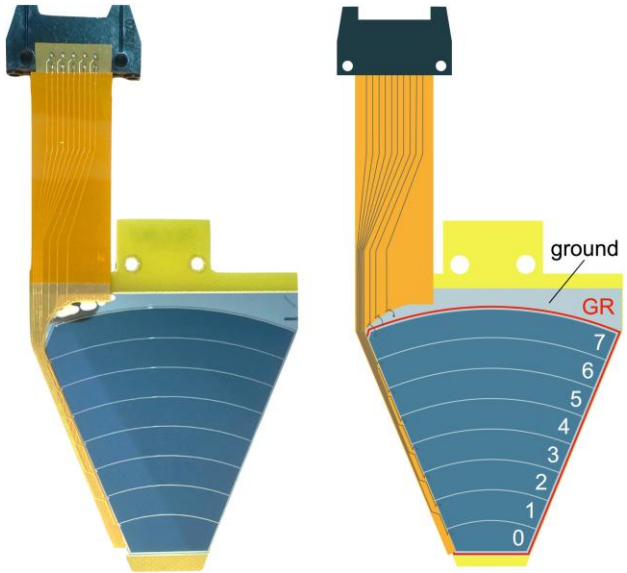
Advanced Gamma Tracking Array (AGATA)

- Highly segmented HPGe crystals
- Tracking capability
- Position resolution: ~3 mm
- Angular coverage: ~1π sr
- Energy resolution: 2.35 keV at 1.3 MeV
- Efficiency: 7-10% at 1.3 MeV

Experimental Apparatus

Silicon Pie Detector (SPIDER)

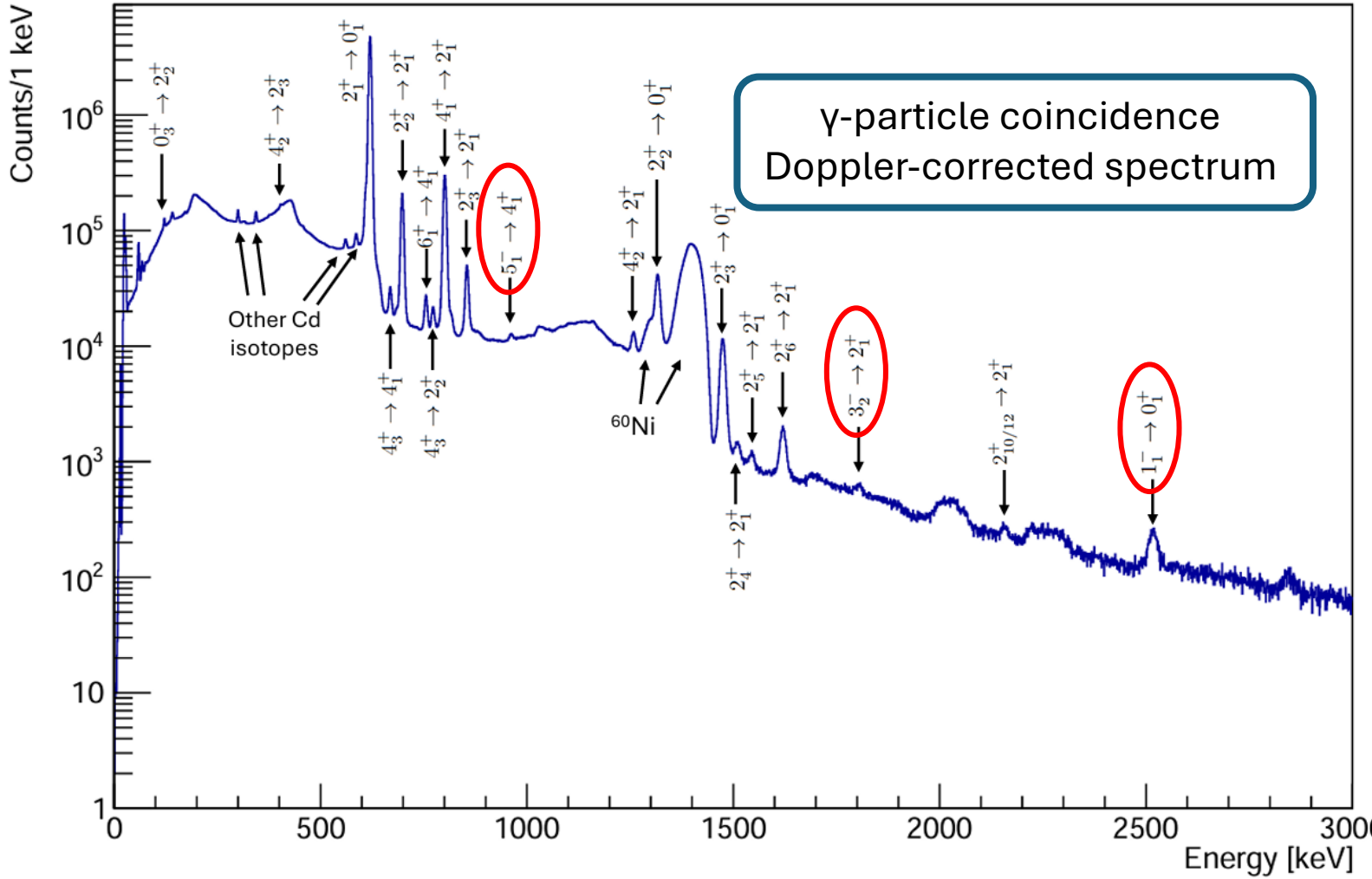
- 7 silicon detectors in cone-like configuration
- 8 strips for each detector
- Angular coverage: [0°,360°] azimuthal, [124°,161°] polar at 8.5 cm from target
- Energy resolution: 15-22 keV
- Leakage current: < 1nA



Data Analysis

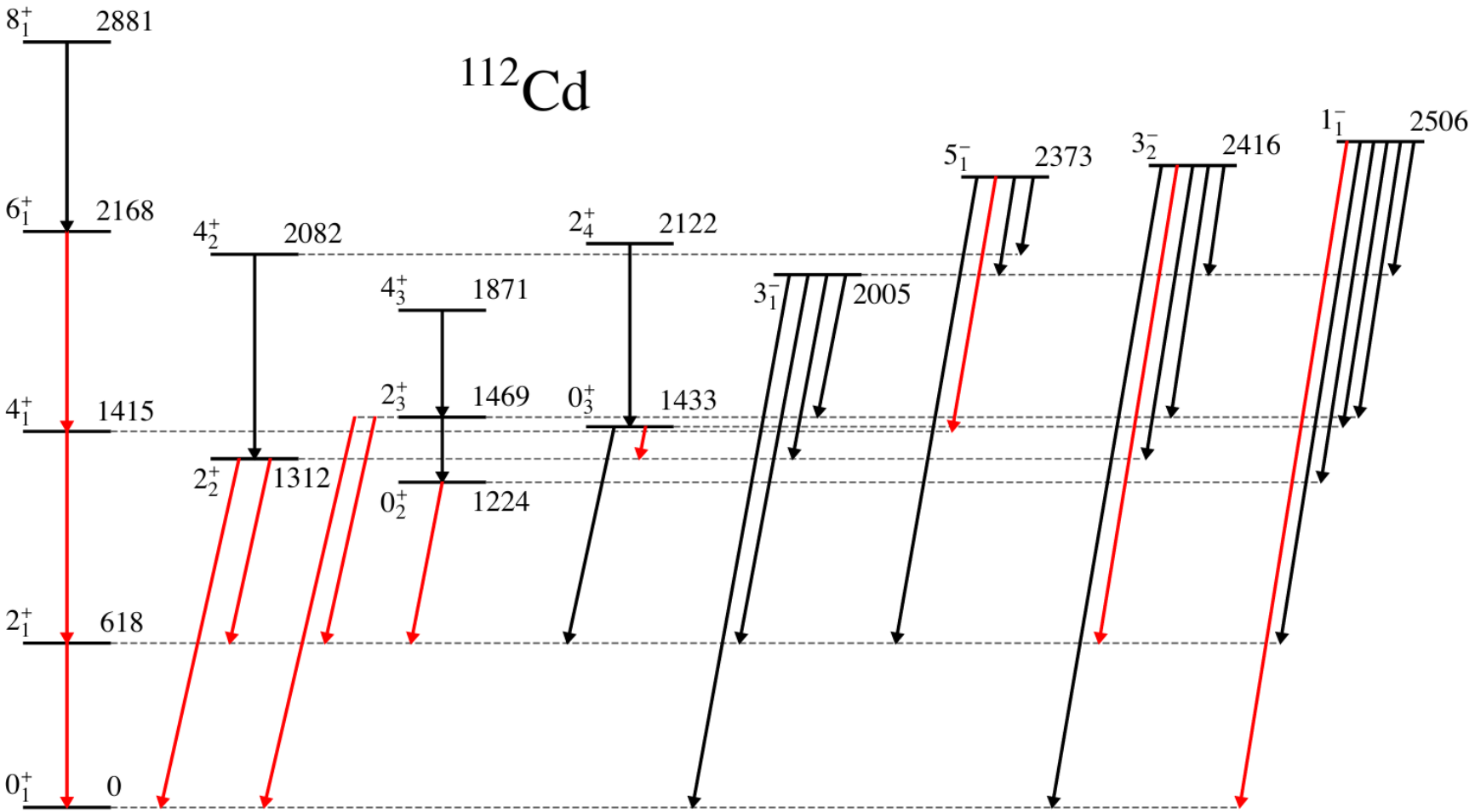
Acquired energy spectrum

- Focus on negative parity states
- Measurement of B(E2) and B(E3) values from experimental yields
- Analysis performed with GOSIA code



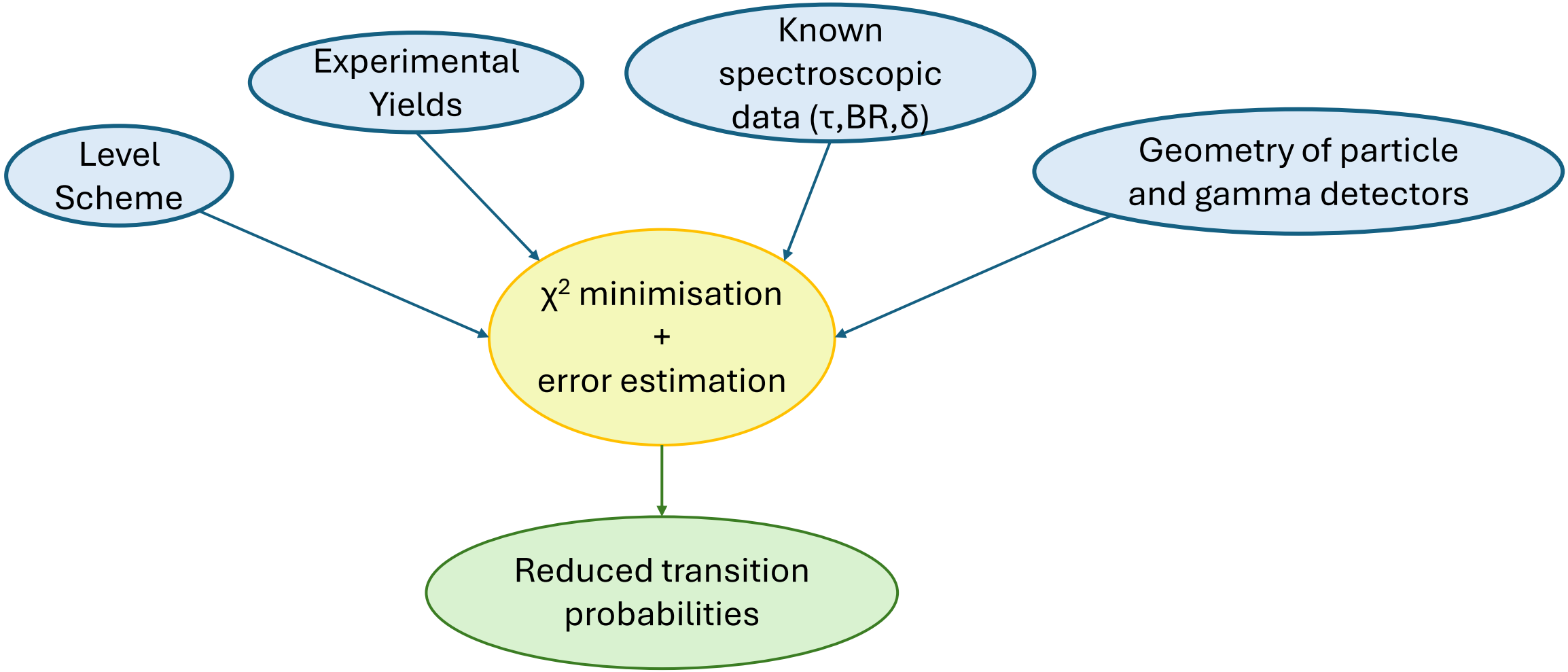
Data Analysis

Reconstructed partial level scheme



Data Analysis

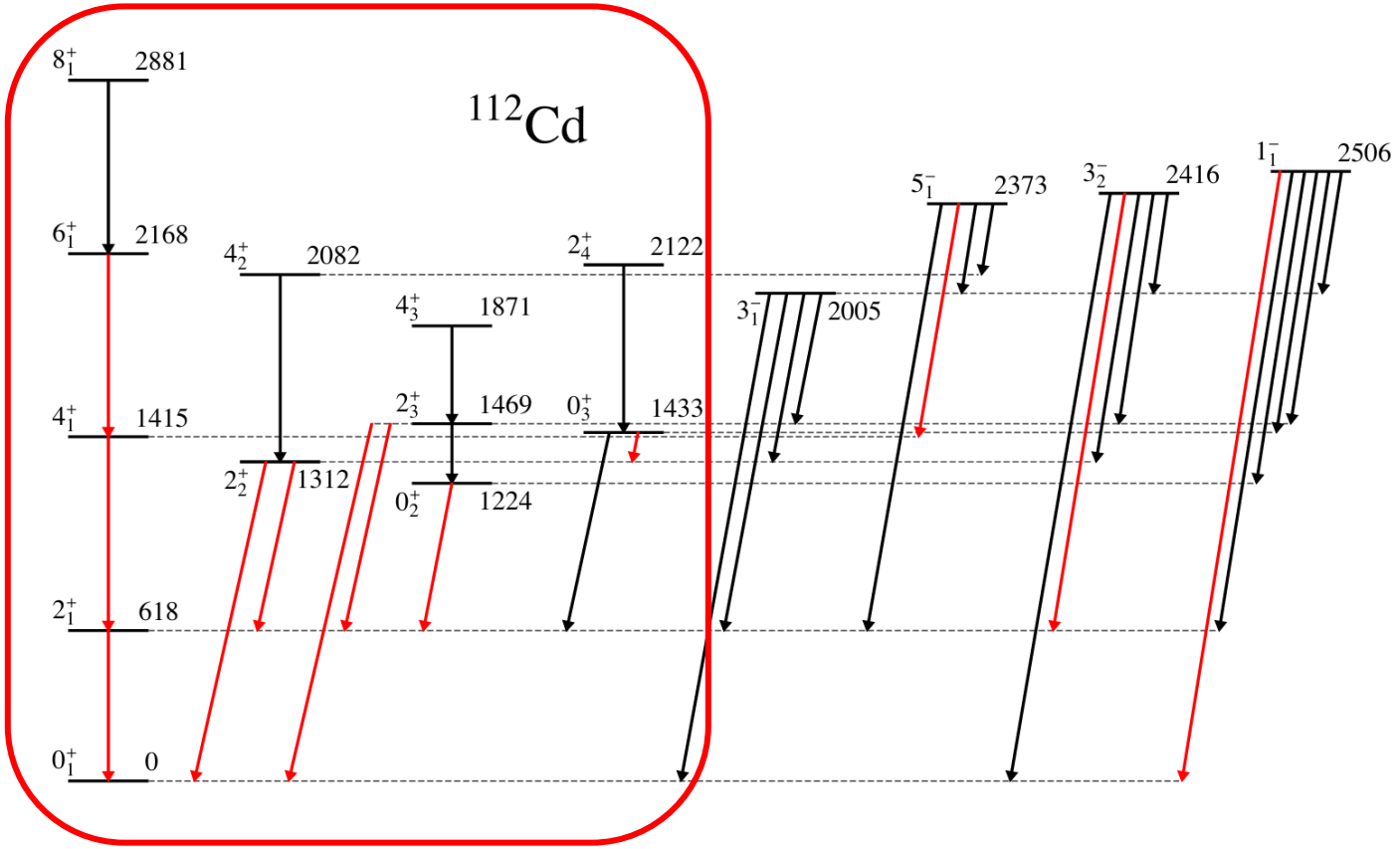
GOSIA code for Coulomb excitation experiments



Data Analysis

Minimisation strategy

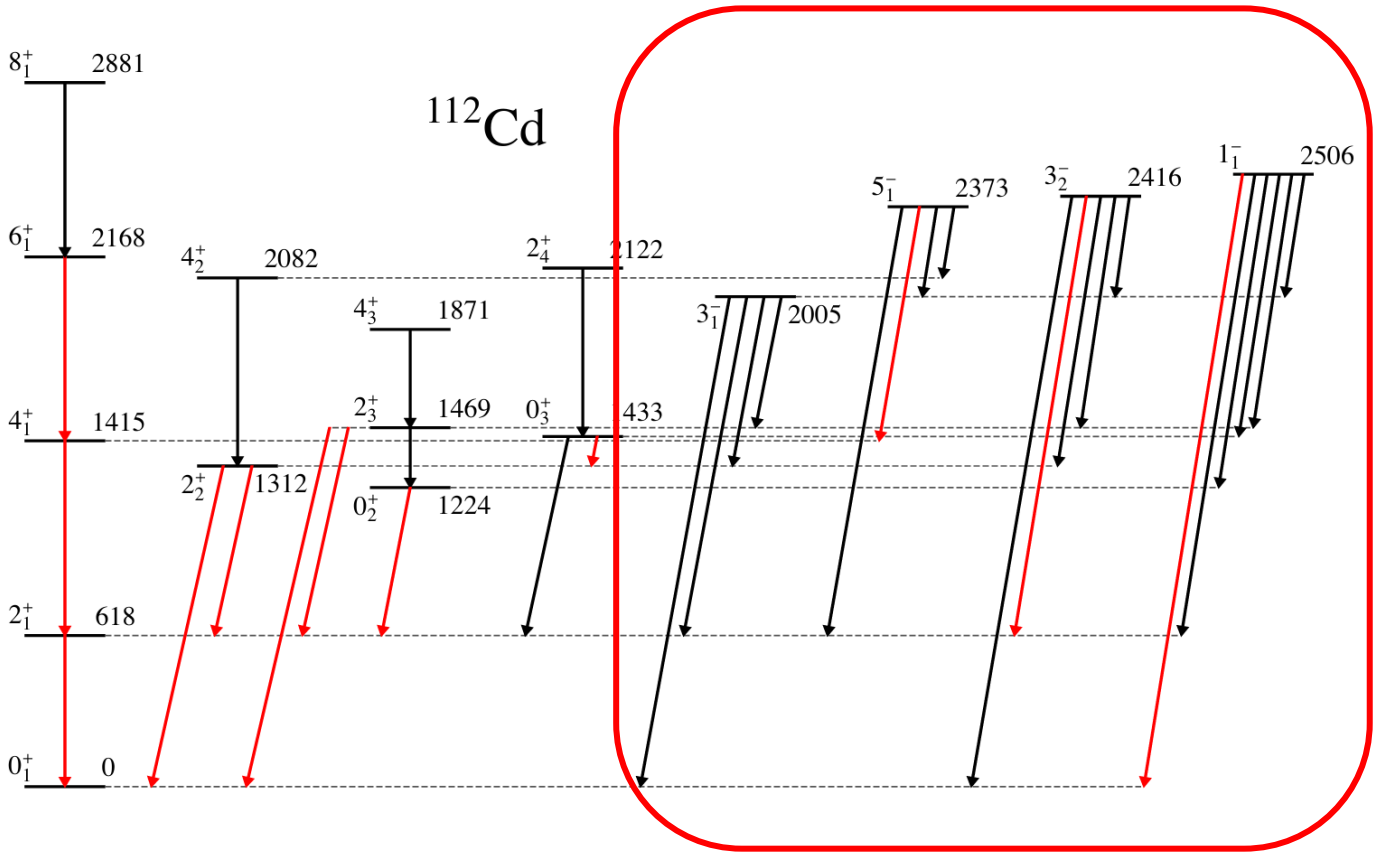
- Initial minimisation on known spectroscopic data for positive parity states
- Second minimisation adding experimental yields for positive parity states



Data Analysis

Minimisation strategy

- Fixed 3_1^- matrix elements to known values (not observed)
- Minimisation on known spectroscopic data for negative parity states
- Final minimisation adding experimental yields for negative parity states



Data Analysis

Preliminary measured reduced transition probabilities

- B(E2;QOCs $\longrightarrow 3_1^-$) measured with unprecedented precision
- B(E3;QOCs $\longrightarrow 2_1^+$) measured for the first time
- B(E3;3_2^- $\longrightarrow 0_1^+$) measured for the first time

Transition	B(E2) [W.u.]	$B(E2)^{Lit}$ [W.u.]
$5_1^- \rightarrow 3_1^-$	57(4)	$58^{+39(a)}_{-37}$
$3_2^- \rightarrow 3_1^-$	82(7)	$85^{+110(a)}_{-66}$
$1_1^- \rightarrow 3_1^-$	55(3)	$<190^{(a)}$
$2_1^+ \rightarrow 0_1^+$	30.2*	$30.2(3)^{(b)}$
Transition	**B(E3) [W.u.]**	**$B(E3)^{Lit}$ [W.u.]**
$5_1^- \rightarrow 2_1^+$	$6.8^{+2.2}_{-1.8}$	
$3_2^- \rightarrow 2_1^+$	14(5)	
$1_1^- \rightarrow 2_1^+$	2.1(6)	
$3_2^- \rightarrow 0_1^+$	2.6(7)	
$3_1^- \rightarrow 0_1^+$	21.8**	$21.8(18)^{(c)}$

* Used as normalisation ** Fixed during minimisation

(a) P. E. Garrett, H. Lehmann, J. Jolie et al. (1999) Quadrupole-octupole coupled states in 112Cd, *Physics Review C* ***59***

(b) https://www.nndc.bnl.gov/ensdf/

(c) Fewell MP , Spear RH , Adam GK Esat MT (1985) Determination of B(E3; 01+ -> 31-) Values for the Stable Isotopes of Cadmium. *Australian Journal of Physics* **38**, 555-562.

Results

QOC states properties

- QOC states' energy at about the sum of single quadrupole and octupole phonons
- 1^-_{QOC} state characterised by a strong E1 transition to the ground state

Already known in the literature

- B(E2;QOCs $\longrightarrow 3_1^-$) of the same magnitude of B(E2;$2_1^+ \longrightarrow 0_1^+$)

- B(E3;QOCs $\longrightarrow 2_1^+$) of the same magnitude of B(E2;$3_1^- \longrightarrow 0_1^+$)

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$3_1^- \rightarrow 0_1^+$	21.8**	21.8(18)$^{(c)}$

Conclusions

- The Coulomb excitation of ^{112}Cd was performed with the AGATA+SPIDER setup at LNL-INFN
- The B(E2) and B(E3) values for transitions concerning the populated negative parity states were obtained in a preliminary analysis
- The data obtained in this work was compared with previous experimental data (if present) and (qualitatively) with QOC states properties predictions
- This preliminary analysis suggests that 5_1^-,3_2^- and 1_1^- states do not behave as ideal QOC states and that ^{112}Cd does not seem to behave as an ideal vibrational nucleus

Thank you for your attention

Spokespersons:
K. Wrzosek-Lipska, A. Nannini, P.E. Garrett, and M. Zielińska

K. Wrzosek-Lipska[a], A. Nannini[b], P.E. Garrett[c], M. Zielińska[d], P. Aguilera[e], Z. Ahmed[c], G. Andreetta[g], F. Angelini[g], M. Balogh[g], J. Benito Garcia[e], V. Bildstein[c], S. Buck[c], D. Brugnara[g], S. Carollo[e], J. Cederkäll[h], G. Colombi[c], G. de Angelis[g], D.T. Doherty[i], C. Fahlander[h], F. Galtarossa[e], A. Goasduff[g], B. Gongora-Servín[g,t], A. Gottardo[g], K. Hadyńska-Klęk[a], S.F. Hicks[k], A. Illana[f] J. Iwanicki[a], G. Jaworski[a], D. Kalaydjieva[c], R. Kjus[d], W. Korten[d], M. Komorowska[a], J. Kowalska[a], S. Lange[c], S.M. Lenzi[e], S. Lunardi[e], N. Marchini[b], K. Mashtakov[c], M. Matejska-Minda[j], M. Mazzocco[e], R. Menegazzo[e], D. Mengoni[e], P.J. Napiorkowski[a], D.R. Napoli[g], R. Nicolás del Álamo[e], B. Olaizola[o], M. Palacz[a], S. Pannu[c], J. Pellumaj[g], R.M. Pérez-Vidal[p], E.E. Peters[k], I. Piętka[a], S. Pigliapoco[e], E. Pilotto[e], L. Próchniak[a], F. Recchia[e], K. Rezynkina[e], M. Rocchini[c], T.R. Rodriguez[l], M. Sedlak[s], P. Sekrecka[a] M. Siciliano[m], F. Simioni[g], A. Stolarz[a] K. Stoychev[c], D. Stramaccioni[g], C. Sullivan[u], C.E. Svensson[c], J.J. Valiente-Dobón[g], J.L. Wood[n], L. Zago[g], I. Zanon[r],

[a] HIL, University of Warsaw, Poland; [b] INFN Firenze, Italy; [c] University of Guelph, Canada; [d] IRFU, CEA, Université Paris-Saclay, France; [e] University of Padova and INFN Padova, Italy; [f] Complutense University of Madrid, Spain; [g] INFN, Laboratori Nazionali di Legnaro, Italy; [h] University of Lund, Sweden; [i] University of Surrey, UK; [j] Polish Academy of Sciences, Cracow, Poland; [k] University of Kentucky, Lexington, USA; [l] Universidad Autónoma de Madrid, Madrid, Spain; [m] Argonne National Laboratory, USA [n] Georgia Institute of Technology, Atlanta, USA; [o] Instituto de Estructura de la Materia, CSIC, Madrid, Spain; [p] IFIC, CSIC - Universitat de València, Spain; [r] KTH Royal Institute of Technology, Stockholm, Sweden; [s] Slovak Academy of Sciences, Bratislava, Slovakia; [t] Università di Ferrara, Italy; [u] University of Liverpool, UK;