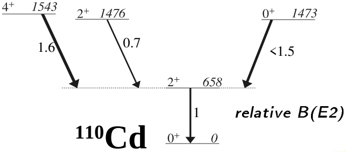
# Probing Multiple Shape Coexistence in $^{110}$Cd with Coulomb Excitation

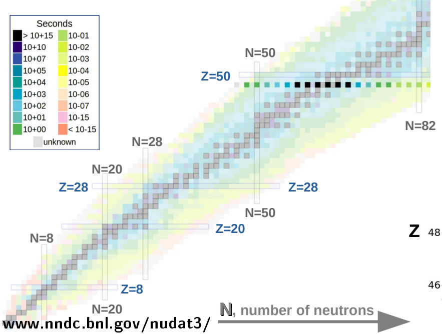
Iwona Piętka
Heavy Ion Laboratory, University of Warsaw

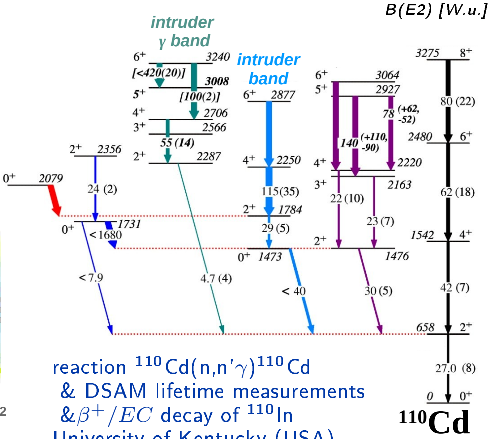
*on behalf of the E22.41 collaboration*

AGATA Collaboration Council
13th September 2024



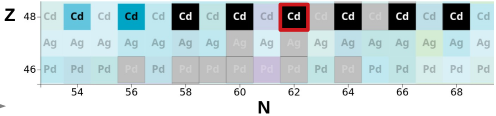

P.E.Garrett *et al.*, PRC86 (2012) 044304




reaction $^{110}$Cd(n,n'$\gamma$)$^{110}$Cd
& DSAM lifetime measurements
& $\beta^+/EC$ decay of $^{110}$In
University of Kentucky (USA)
& TRIUMF laboratory (Canada)

P.E.Garrett *et al.*, PRL123 (2019) 142502



# $^{110}$Cd – from vibrational structure to shape coexistence?

## Theoretical models

**A** **a vibrational picture**

The concept of a partial dynamical symmetry in the **U(5) Hamiltonian**.
Most of the low-lying normal states in $^{110\text{-}116}$Cd maintain their spherical-vibrational character and few non-yrast states exhibit a departure from U(5) symmetry.

A. Leviatan et al., PRC 98, 031302(R) (2018)  N. Gavrielov, et al., Phys. Rev. C 108, L031305 (2023)

**B** **a multiple shape-coexistence**

**I** **beyond-mean-field** (BMF) calculations using the **symmetry conserving configuration mixing** (SCCM) method with the **Gogny D1S** energy density functional

P.E.Garrett, T.R.Rodríguez *et al.*, Phys.Rev.Lett. 123 (2019) 142502
P.E.Garrett, T.R.Rodríguez *et al.*, Phys.Rev.C101 (2020) 044302

**II** General Bohr Hamiltonian
using Skyrme interactions SLy4 or energy density functional UNEDF0

K.Wrzosek-Lipska, L.Próchniak *et al.*, Acta Phys.Pol.B51 (2020) 789

# Shape coexistence hypothesis

## Theoretical models

B **a multiple shape-coexistence**

I **beyond-mean-field** (BMF) calculations using the **symmetry conserving configuration mixing** (SCCM) method with the **Gogny D1S** energy density functional

P.E.Garrett, T.R.Rodríguez *et al.*, Phys.Rev.Lett. 123 (2019) 142502
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## shape coexistence

| *nuclear state* | | *shape* |
|---|---|---|
| 0 keV | $0_1^+$ | prolate |
| 1473 keV | $0_2^+$ | triaxial |
| 1731 keV | $0_3^+$ | oblate |

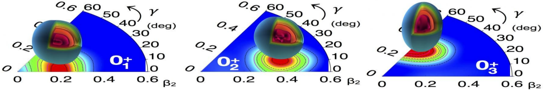
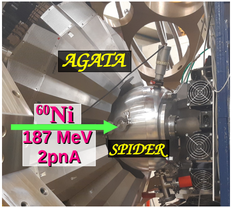
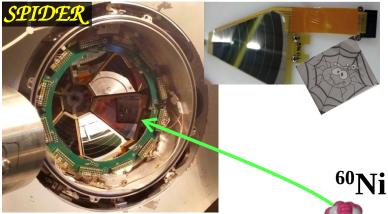



Fig.:Shape Coexistence Workshop - 2023 | Physics (uoguelph.ca)
BMF-SCCM calculation

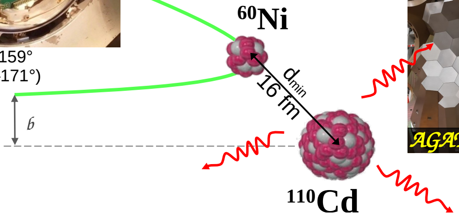
# Coulomb excitation of $^{110}$Cd with $^{60}$Ni at LNL

*June 2022: 1 day 10 hours*
*October 2022: 3 days 12 hours*



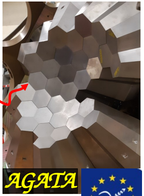




$\theta_{LAB}$ = 128°–159°
($\theta_{CM}$ = 151°–171°)




Istituto Nazionale di Fisica Nucleare

$\theta_{LAB}$ = 65°–160°




$^{110}$Cd: 0.928(55) mg/cm$^2$
carbon layer: 0.017(3) mg/cm$^2$
measured by LABEC-INFN, Florence

## Silicon PIe DEtectoR

7 silicon detectors segmented into 8 annular strips

## Advanced GAmma Tracking Array

- 11 ATC; close-up position
- efficiency 4.6% for 1408 keV


J.J.Valiente-Dobón, R. Menegazzo, A. Goasduff *et al.*, Nucl.Instr.Meth.A1049 (2023) 168040.
M.Rocchini, K. Hadyńska-Klęk, A. Nannini *et al.*, Nucl.Instr.Meth.A971 (2020) 164030

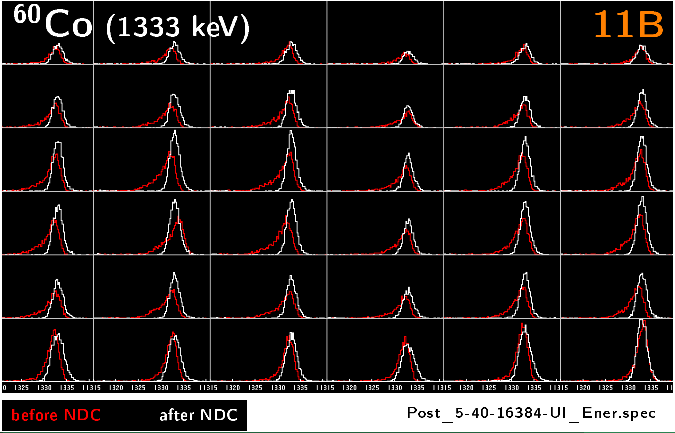
# The Post Pulse Shape Analysis (PostPSA)

## AGATA crystals

| | | |
|---|---|---|
| 00A | 00B | 00C |
| 01A | 01B | 01C |
| 02A | 02B | 02C |
| 04A | 04B | ~~04C~~ |
| 05A | 05B | |
| 06A | 06B | 06C |
| 07A | 07B | ~~07C~~ |
| 08A | 08B | 08C |
| 09A | 09B | 09C |
| 10A | 10B | 10C |
| 11A | 11B | 11C |

2 crys. – excluded during experiment

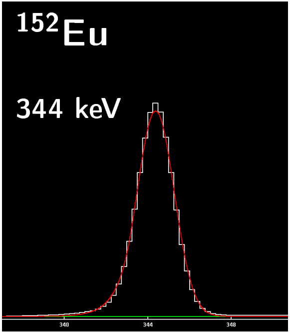
8 crys. – need neutron damage corrections



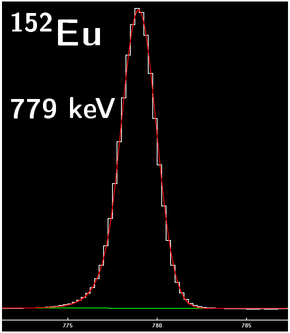

Post_5-40-16384-UI_Ener.spec

# The Post Pulse Shape Analysis (PostPSA)

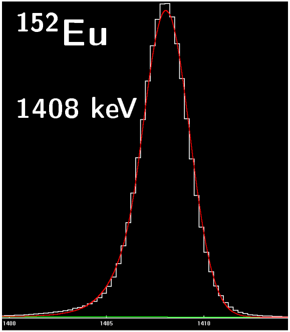
- ✓ Neutron damage corrections
- ✓ Final energy re-calibrations
- ✓ Force Segments to Core
- ✓ Global time alignments




FWHM = 2.023(1) keV




FWHM = 2.334(1) keV

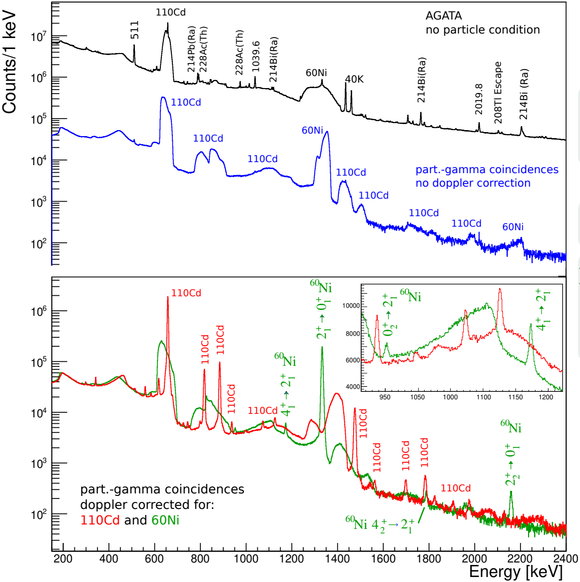



FWHM = 2.857(1) keV

Track_2-15-16384-UI_EE.spec

Tracked spectrum[0][2]

# Data analysis




Coulomb excitation of **projectile $^{60}$Ni** or **recoil $^{110}$Cd**

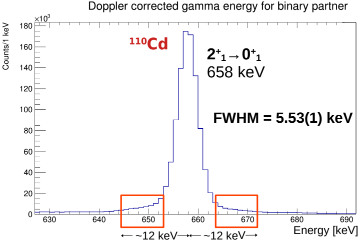
**I particle ($^{60}$Ni) – $\gamma$ coincidence**

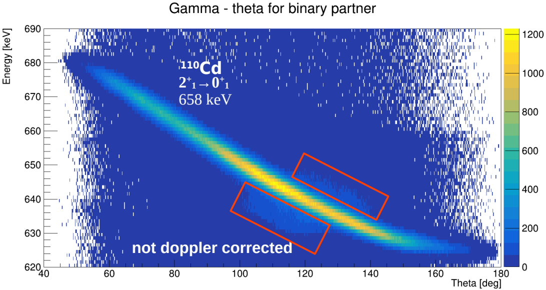
**II Doppler correction**

- projectile $^{60}$**Ni**
- recoil $^{110}$**Cd**

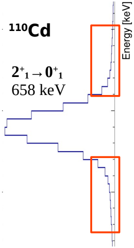
| energy [keV] | FWHM [keV] |
|---|---|
| 658 | 5.5(1) |
| 1476 | 8.8(1) |

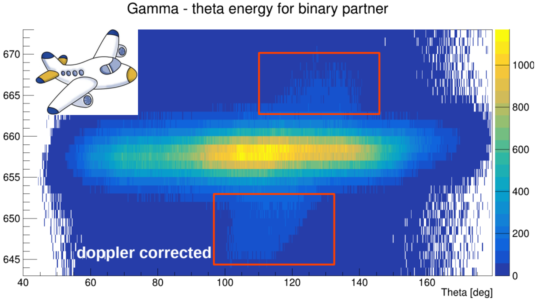
# Data analysis – "wings" in the γ-ray spectrum



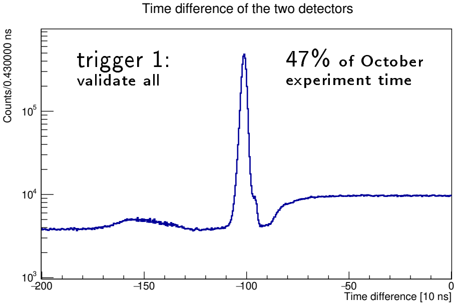



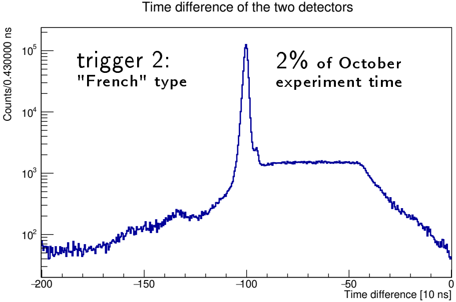

6% of total peak intensity



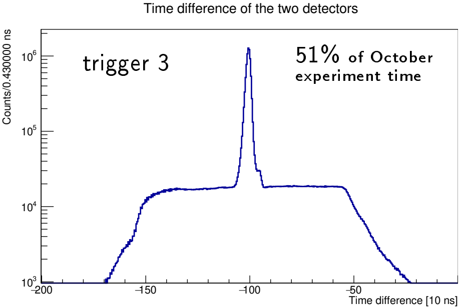



# Data analysis – trigger



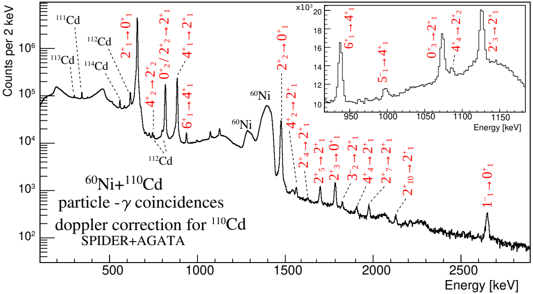

**Timing spectra:**
**particle - $\gamma$ coincidence**



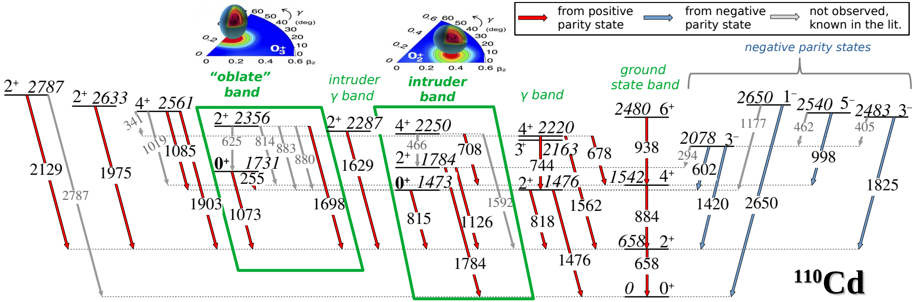

time difference between
$\gamma$-ray (AGATA)
and
particle (SPIDER)

# Coulomb excitation of $^{110}$Cd with $^{60}$Ni beam

K.Wrzosek-Lipska *et al.*, LNL Annual Report 2022 (INFN-LNL-273/2023), page 24




- 19 excited states
- energy up to 2.8 MeV
- both parities (+ and −)
- intruder band ($0^+_2$)
- "oblate" band ($0^+_3$)



# Summary

The safe **Coulomb-excitation of $^{110}$Cd with $^{60}$Ni beam**, using AGATA + SPIDER setup, performed at LNL

## the Post Pulse Shape Analysis

- ✓ Neutron damage corrections
- ✓ Final energy re-calibrations
- ✓ Force Segments to Core
- ✓ Global time alignments

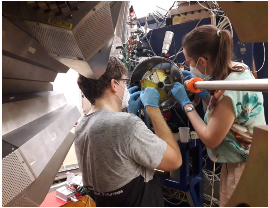
- ✓ identification of the $\gamma$-ray transitions in the spectrum of $^{110}$Cd

## next steps:

- analysis of particle-$\gamma$ timing spectra collected with different triggers
- investigating the "wings" issue in the $\gamma$-ray spectrum
- data division in terms of the scattering angle of $^{60}$Ni projectile
- extraction of matrix elements in $^{110}$Cd (GOSIA analysis)

E22.41 collaboration: IP[1], L. Próchniak[1], K. Wrzosek-Lipska[1], P.E. Garrett[2], A. Nannini[3], M. Rocchini[2,3], M. Zielińska[4], P. Aguilera[5,6], Z. Ahmed[2], F. Angelini[6,7], M. Balogh[7], J. Benito[5,6,19], H. Bidaman[2], V. Bildstein[2], D. Brugnara[7], S. Buck[2], S. Carollo[5], J. Cederkäll[8], R. Coleman[2], G. Colombi[9,17,18], D.T. Doherty[10], A. Ertoprak[7], R. Escudeiro[5], F. Galtarossa[5], A. Goasduff[7] , B.Góngora-Servín[7,11], A. Gottardo[7], A. Gozzelino[7], B. Greaves[2], K. Hadyńska-Klęk[1], S.F. Hicks[12], Z. Huang[5], A. Illana[13], D. Kalaydjieva[2,4], M. Komorowska[1], J. Kowalska[1], K. Krutul[1], N. Marchini[3], M. Matejska-Minda[14], D. Mengoni[5,6], P.J. Napiorkowski[1], D.R. Napoli[7], S. Pannu[2], J. Pellumaj[7,11], R.M. Pérez-Vidal[7,15], S. Pigliapoco[5,6], E. Pilotto[5,6], F. Recchia[5,6], K. Rezynkina[5,6], M. Sedlák[7,20], A. Stolarz[1], K. Stoychev[2,16], C.E. Svensson[2], S. Valbuena[2], J.J. Valiente-Dobón[7], L. Zago[6,7], I. Zanon[7], G. Zhang[5], T. Zidar[2]

[1] *HIL, University of Warsaw, Poland;*
[2] *Department of Physics, University of Guelph, Canada;*
[3] *INFN, Sezione di Firenze, Italy;*
[4] *IRFU, CEA, Université Paris-Saclay, France;*
[5] *INFN, Sezione di Padova, Italy;*
[6] *Dipartimento di Fisica, Università di Padova, Italy;*
[7] *INFN, Laboratori Nazionali di Legnaro, Italy;*
[8] *Department of Physics, Lund University, Sweden;*
[9] *Institut Laue-Langevin, Grenoble, France;*
[10] *Department of Physics, University of Surrey, UK;*
[11] *Dipartimento di Fisica e Scienze della Terra, Università di Ferrara, Italy;*
[12] *Department of Physics, University of Dallas, Irving, Texas, USA;*
[13] *Accelerator Laboratory, Department of Physics, University of Jyväskylä, Finland;*
[14] *Polish Academy of Sciences, Kraków, Poland;*
[15] *IFIC, CSIC - Universitat de Valéncia, Spain;*
[16] *IJCLab, Université Paris-Saclay, France;*
[17] *Dipartimento di Fisica, Università di Milano, Italy;*
[18] *INFN, Sezione di Milano, Italy;*
[19] *Faculty of Physics, University Complutense of Madrid, Spain;*
[20] *Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia*



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