Octupole collectivity in ^{96}Zr from low-energy Coulomb excitation with the AGATA+SPIDER setup (22.18)

Federica Ercolano, Master Thesis

Collaboration

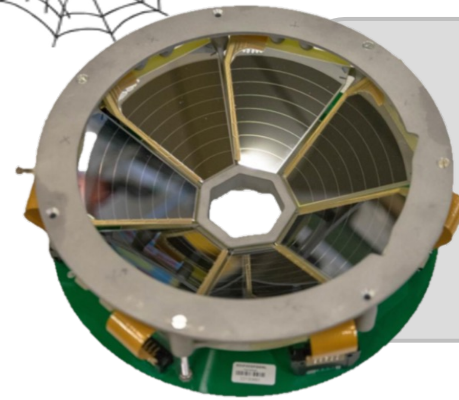
F. Ercolano[1], N. Marchini[2], D.T. Doherty[3], M. Zielińska[4], M. Rocchini[2], A. Nannini[2], P.E. Garrett[5], K. Hadyńska-Klęk[6], M. Balogh[7], P. Aguilera[7], F. Angelini[7], D. Bazzacco[7], J. Benito[7,9], G. Benzoni[8], D. Brugnara[7], S. Buck[5], F. Camera[8], R. Coleman[5], R. Escudeiro[7,9], A. Ertoprak[7], G. de Angelis[7], F. Galtarossa[7,9], N. Gelli[2], A. Goasduff[7], B. Gongora[7], A. Gottardo[7], A. Gozzelino[7], D. Kalaydjieva[4], W. Korten[3], Md. S. R. Laskar[8], M. Matejska-Minda[10], D. Mengoni[7,9], D. Napoli[7], M. Ottanelli[2], G. Pasqualato[11], J. Pellumaj[7], R.M. Pérez-Vidal[7], S. Pigliapoco[7,9], E. Pilotto[7], F. Recchia[7,9], K. Rezynkina[9], K. Stoychev[11], J. J. Valiente Dobón[7], K. Wrzosek-Lipska[6], L. Zago[7], G. Zhang[9],1. Zanon[7], T. Zidar[5]

[1] INFN Sezione di Napoli, Naples, Italy; [2] Università degli studi di Firenze, Dipartimento di Fisica, Florence and INFN Sezione di Firenze, Florence, Italy; [3] Department of Physics, University of Surrey, Guildford, UK; [4] IRFU, CEA Saclay, Université Paris-Saclay, France; [5] University of Guelph, Guelph, Canada; [6] Heavy Ion Laboratory, University of Warsaw, Poland; [7] INFN, Laboratori Nazionali di Legnaro, Legnaro (Padova), Italy; [8] INFN Sezione di Milano, Milano, Italy; [9] Università degli Studi di Padova, Padova, Italy; [10] IFJ-PAN, Kraków, Poland; [11] IJCLab, Université Paris-Saclay, France

Coulomb excitation of ^{96}Zr at LNL (22.18)

- data taking: October 21-25, 2022
- beam: ^{58}Ni, 160 MeV, 3 pnA
- target: ^{96}Zr, self-supporting

AGATA array (11 ATCs), close-up position.

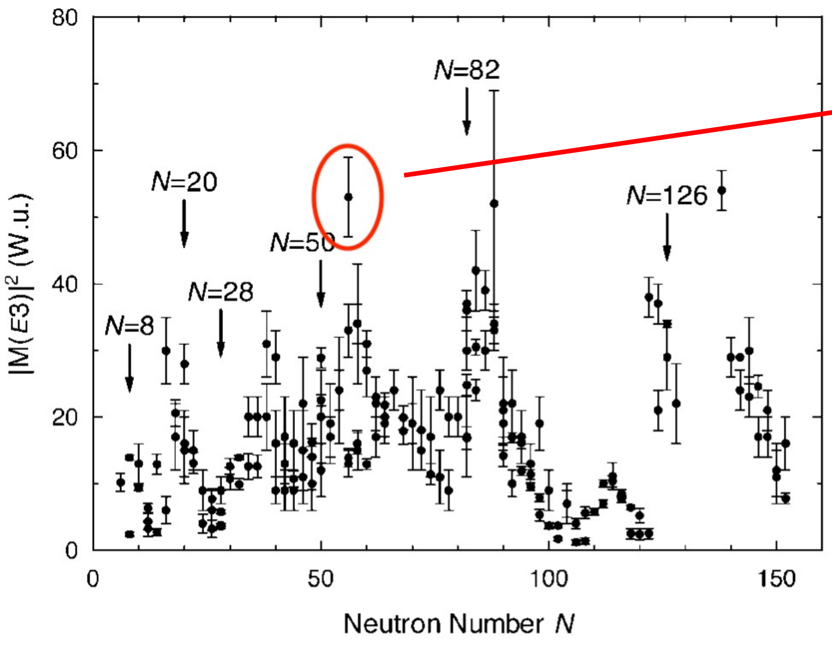


SPIDER: a modular array of 7 Si detectors, each segmented into 8 annular strips (junction side)
$\vartheta_{LAB} = 126° - 162°$
(detection of back-scattered ^{58}Ni ions)

Goal of the experiment: quadrupole moments of $2^{+}_{1,2}$ states

Goal of the MSc thesis: investigation of the 3^{-}_{1} state properties

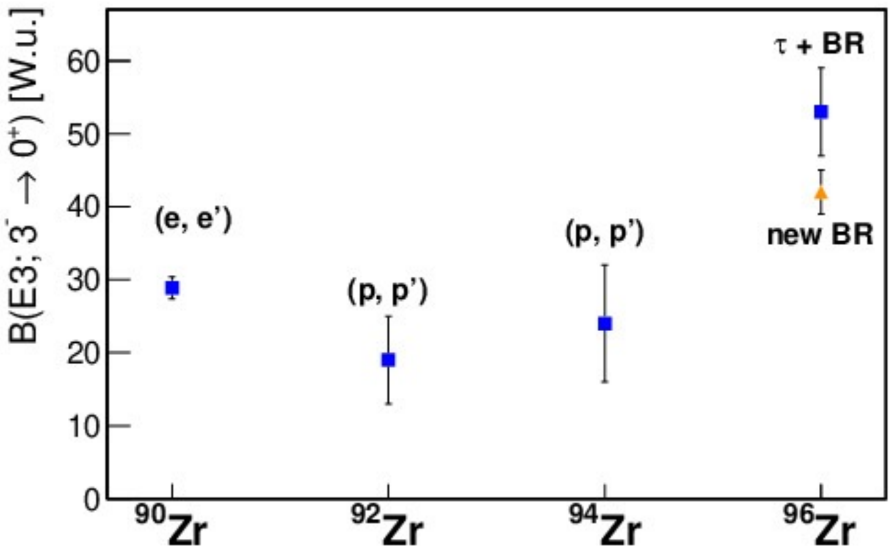
Octupole collectivity in Zr isotopes: the ^{96}Zr anomaly



T. Kibédi and R.H. Spear, At. Data Nucl. Data Tables 80, 35 (2002)

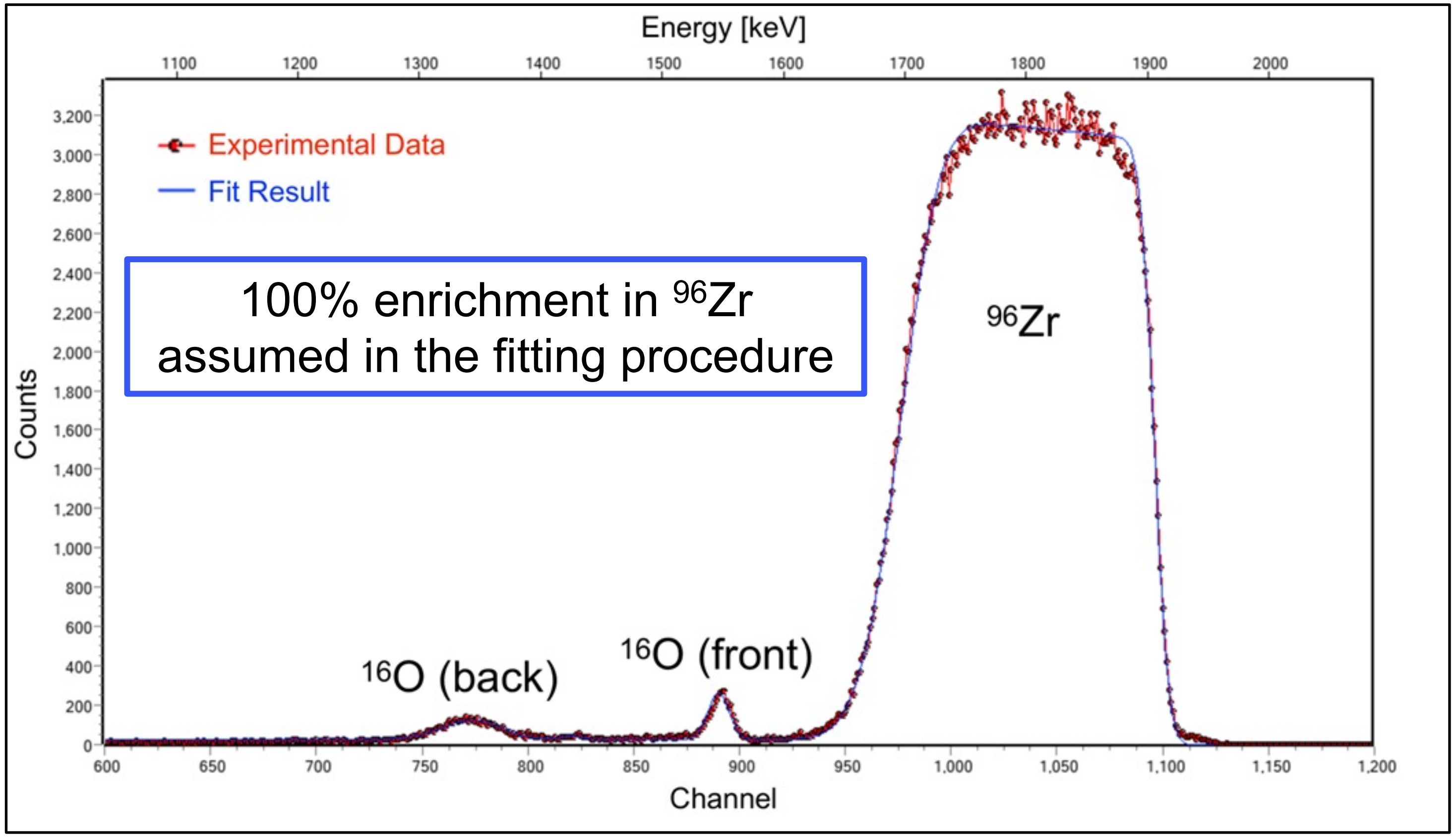
- B(E3, $3_1^- \rightarrow 0_1^+$) value in ^{96}Zr strikingly high (evaluated value: 53(6) W.u.); long-standing challenge for theory.

- **New measurement** of the E1/E3 branching ratio in the decay of the 3$^-$ state (Ł. Iskra *et al*, Phys. Lett. B 788 (2019) 396) points to lower octupole collectivity



^{96}Zr target used in the LNL study

- Problems to buy enriched ^{96}Zr material for the targets due to the Russia-Ukraine war
- Several metallic ^{96}Zr targets loaned from other laboratories (Argonne, Bucharest), but with a lower isotopic enrichment than reported
- An RBS study of the ^{96}Zr target used at LNL was performed after the measurement at the LABEC laboratory in Florence:
  - oxidized front and back surfaces of the target;
  - target thickness: 690 μg/cm^2

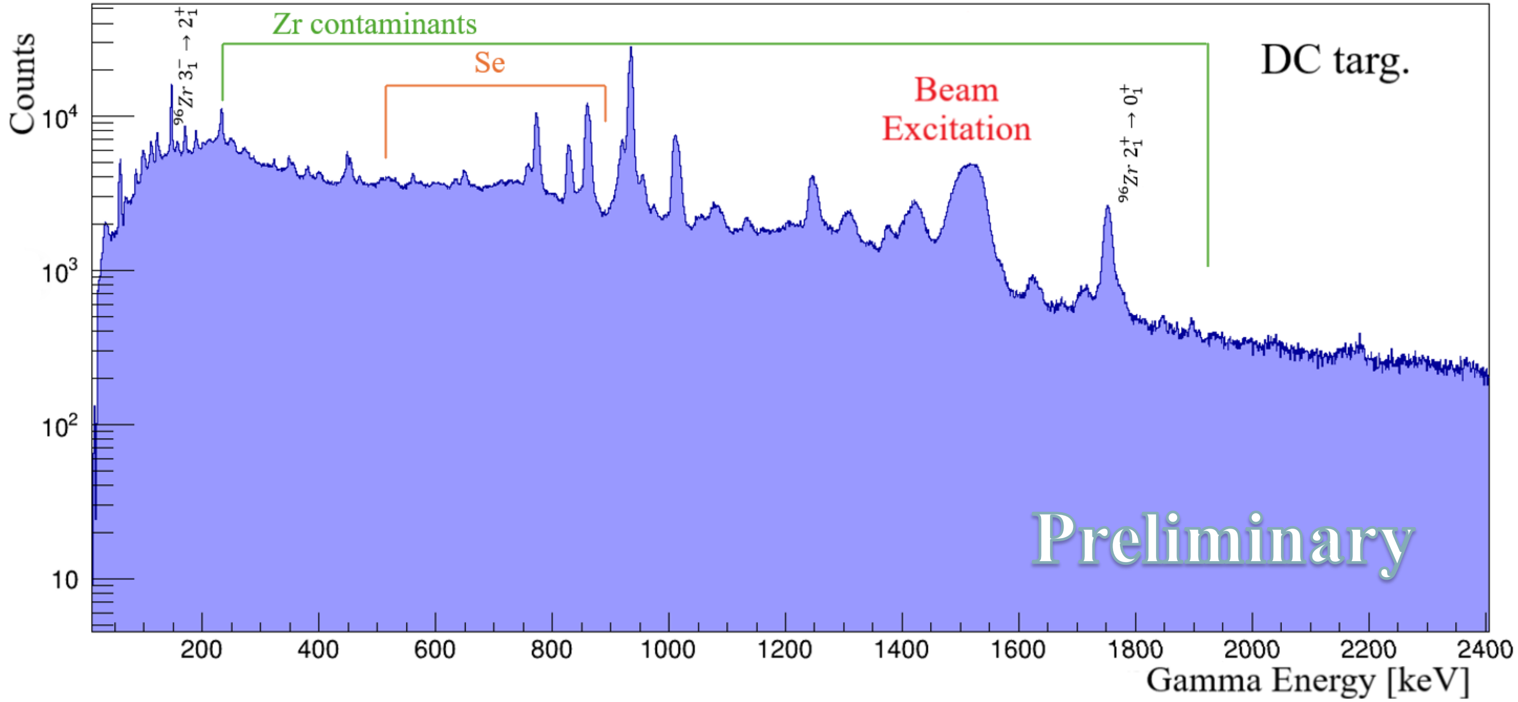


RBS spectrum measured at LABEC for the ^{96}Zr target used at LNL

Coulomb excitation of ^{96}Zr at LNL: total γ-ray spectrum

- Transitions in other Zr isotopes (^{90}Zr, ^{92}Zr, ^{94}Zr) present in the spectrum due to significant isotopic impurity of the target

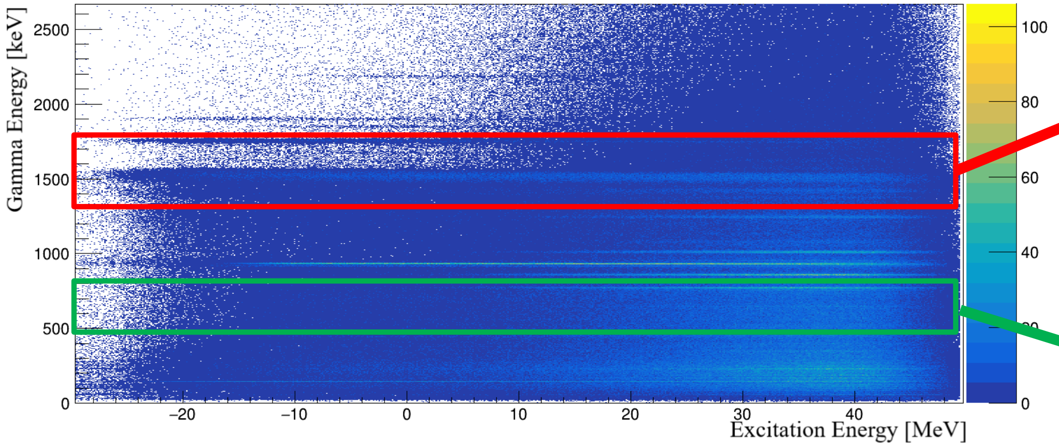
- Oxidized front and back surfaces of the target – ^{58}Ni + ^{16}O fusion-evaporation reaction leading to intense transitions in ^{72}Se, ^{72}Br, ^{69}As



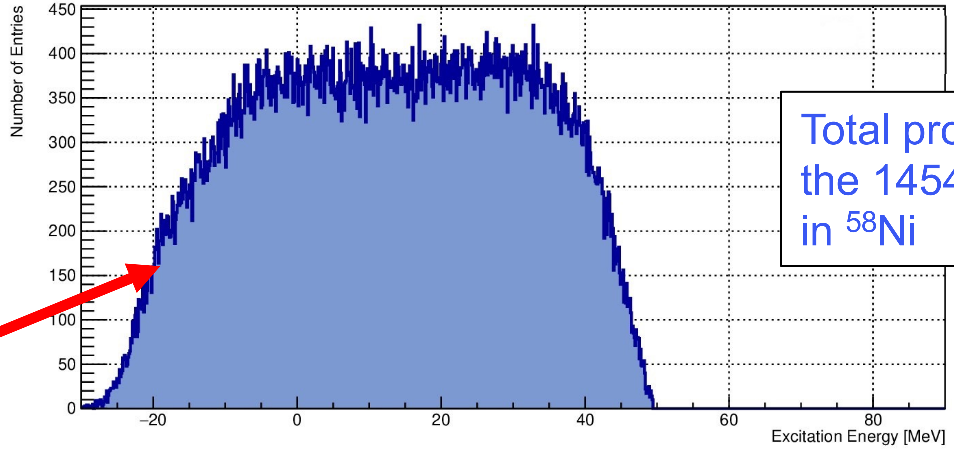
Total γ-ray energy spectrum, acquired in coincidence with the back-scattered ^{58}Ni ions, Doppler corrected for the target nuclei

Cuts on excitation-energy spectrum

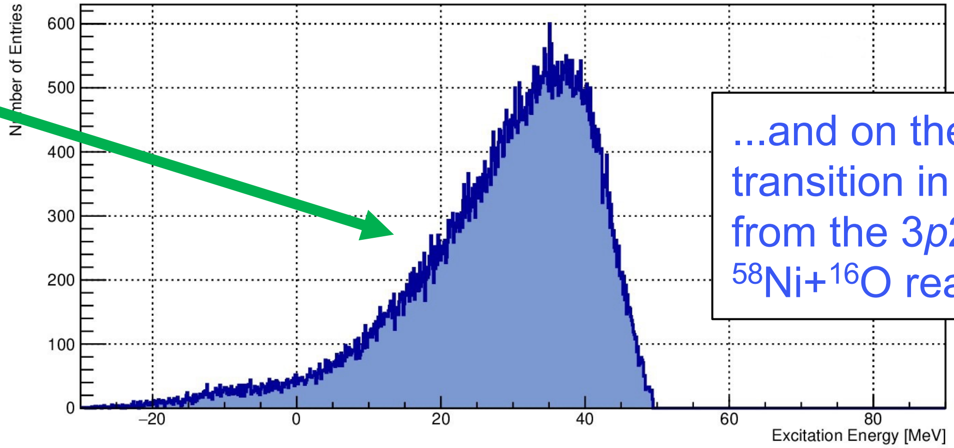
Gates were applied on the excitation energy to suppress the fusion-evaporation background:



γ-ray energies, Doppler-corrected for the target nuclei, *versus* total excitation energy of the ^{58}Ni + ^{96}Zr system



Total projection gated on the 1454-keV transition in ^{58}Ni



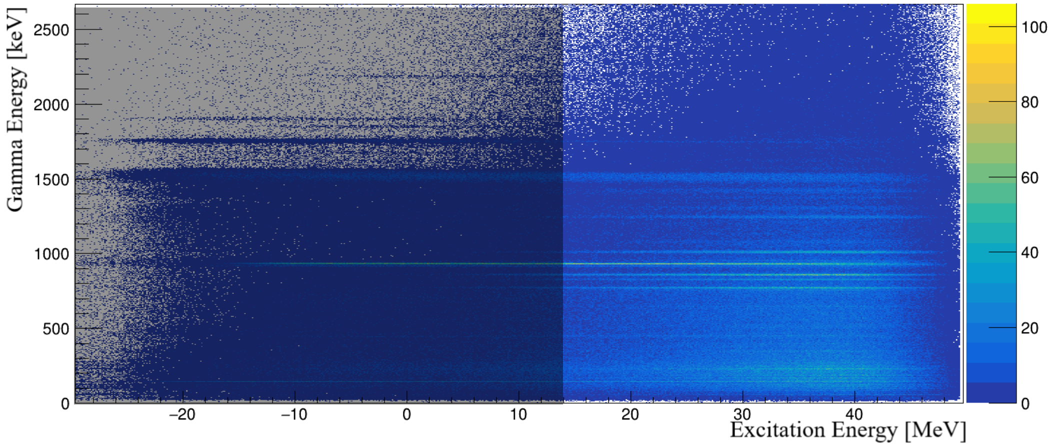
...and on the 662-keV transition in ^{69}As (originating from the 3*p*2*n* channel of the ^{58}Ni+^{16}O reaction)

Very different patterns – suppression of fusion-evaporation events possible

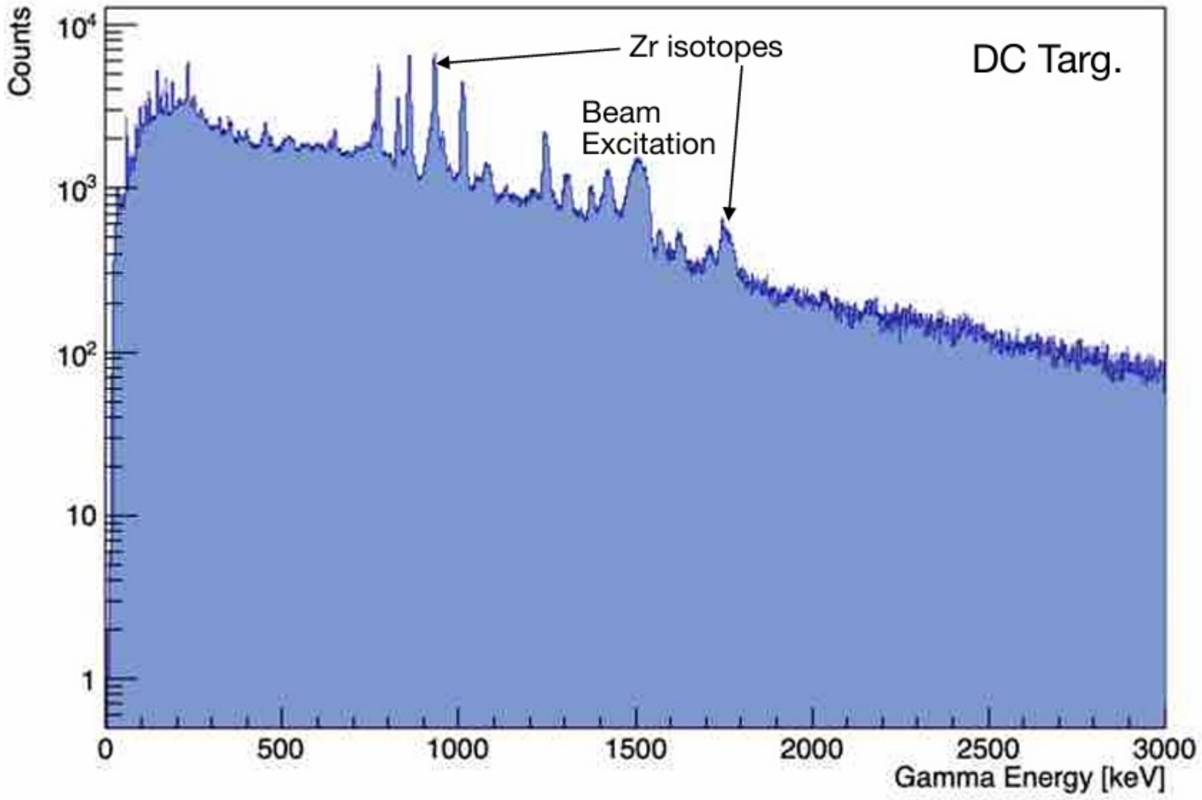
Cuts on excitation-energy spectrum

Gates were applied on the excitation energy to suppress the fusion-evaporation background:

Gate on a range with strong fusion-evaporation channels:



γ-ray energies, Doppler-corrected for the target nuclei, *versus* total excitation energy of the ^{58}Ni + ^{96}Zr system

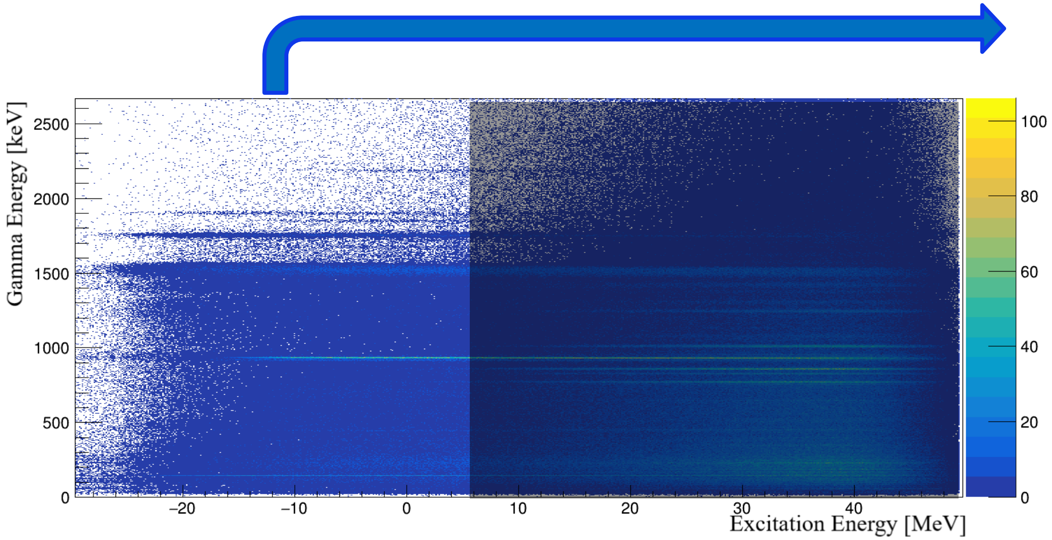


Projection of the matrix on the y axis, obtained with a gate on the x axis (14 - 50 MeV)

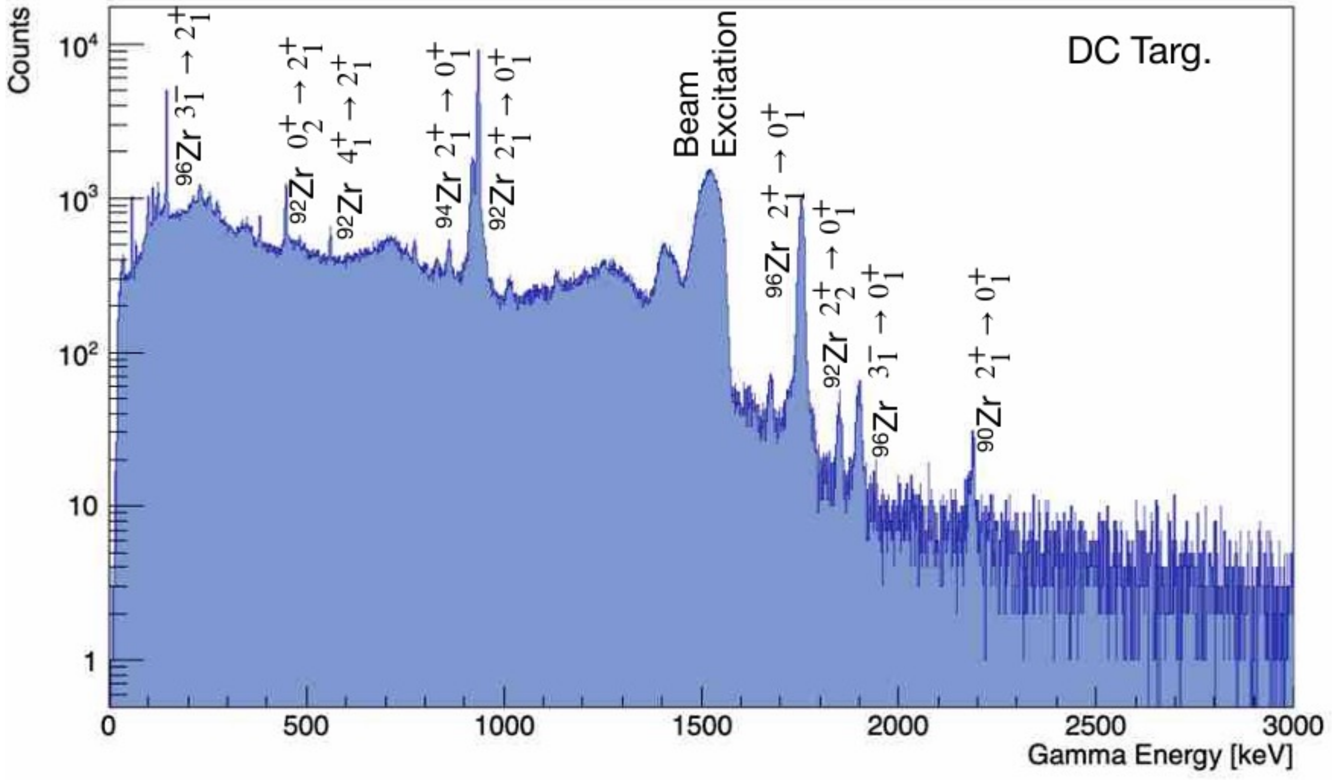
Cuts on excitation-energy spectrum

Gates were applied on the excitation energy to suppress the fusion-evaporation background:

Gate on a range with mostly Coulomb excitation:



γ-ray energies, Doppler-corrected for the target nuclei, *versus* total excitation energy of the ^{58}Ni + ^{96}Zr system



Projection of the matrix on the y axis, obtained with a gate on the x axis (-30 - 6 MeV)

F. Ercolano, MSc thesis, 2024

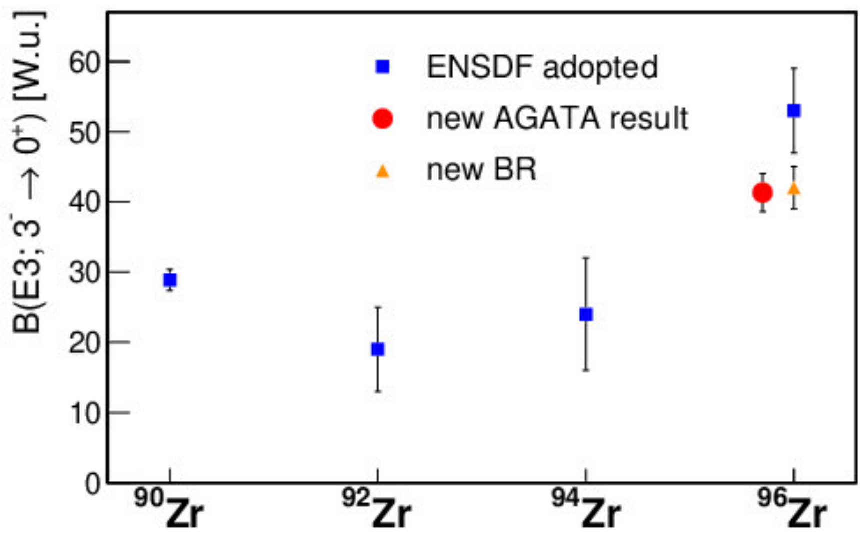
Preliminary results

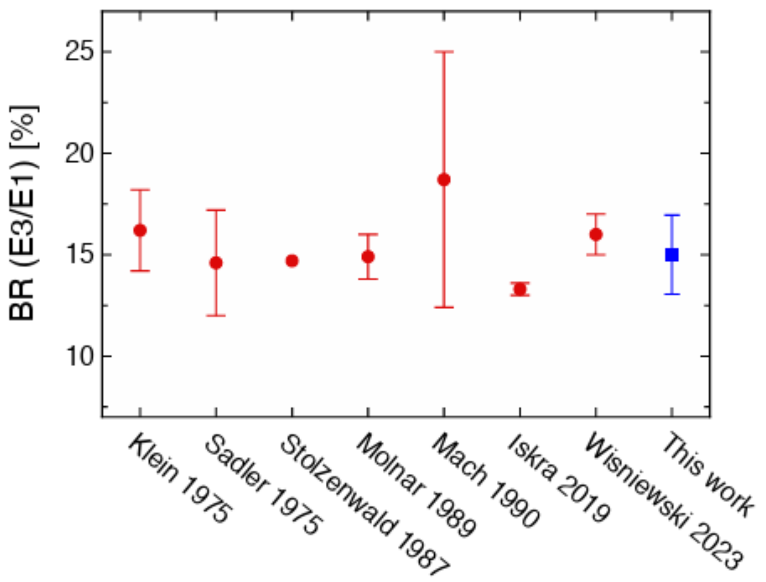
Transition probabilities in ^{96}Zr determined from the measured γ-ray intensities:

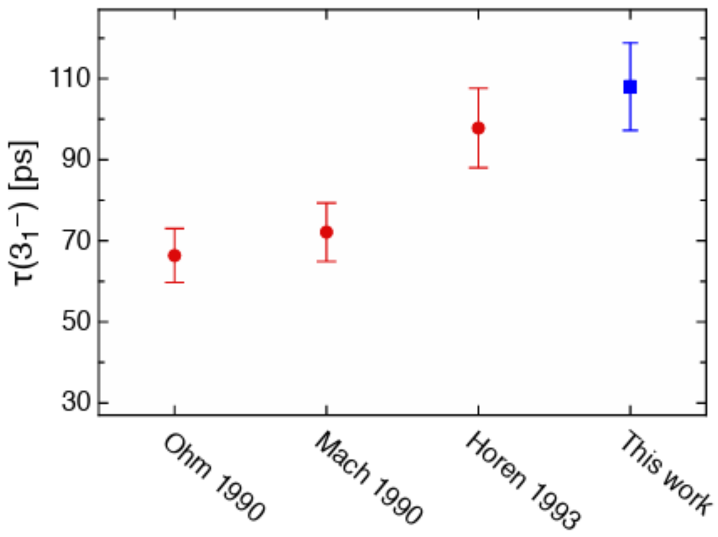
$$B(E3; 3_1^- \rightarrow 0_1^+) = 41(3)\ \mathrm{W.u.}$$

$$B(E1; 3_1^- \rightarrow 2_1^+) = 114(13) \cdot 10^{-4}\ \mathrm{W.u.}$$

Obtained value in good agreement with the B(E3; $3_1^- \rightarrow 0_1^+$) = 42(3) W.u. from Ł. Iskra *et al*, Phys. Lett. B 788 (2019) 396







The deduced $3_1^- \rightarrow 0_1^+ / 3_1^- \rightarrow 2_1^+$ branching ratio and the lifetime of the 3_1^- state in ^{96}Zr are in agreement with the most recent measurements

Collaboration

F. Ercolano[1], N. Marchini[2], D.T. Doherty[3], M. Zielińska[4], M. Rocchini[2], A. Nannini[2], P.E. Garrett[5], K. Hadyńska-Klęk[6], M. Balogh[7], P. Aguilera[7], F. Angelini[7], D. Bazzacco[7], J. Benito[7,9], G. Benzoni[8], D. Brugnara[7], S. Buck[5], F. Camera[8], R. Coleman[5], R. Escudeiro[7,9], A. Ertoprak[7], G. de Angelis[7], F. Galtarossa[7,9], N. Gelli[2], A. Goasduff[7], B. Gongora[7], A. Gottardo[7], A. Gozzelino[7], D. Kalaydjieva[4], W. Korten[3], Md. S. R. Laskar[8], M. Matejska-Minda[10], D. Mengoni[7,9], D. Napoli[7], M. Ottanelli[2], G. Pasqualato[11], J. Pellumaj[7], R.M. Pérez-Vidal[7], S. Pigliapoco[7,9], E. Pilotto[7], F. Recchia[7,9], K. Rezynkina[9], K. Stoychev[11], J. J. Valiente Dobón[7], K. Wrzosek-Lipska[6], L. Zago[7], G. Zhang[9],1. Zanon[7], T. Zidar[5]

[1] *INFN Sezione di Napoli, Naples, Italy;* [2] *Università degli studi di Firenze, Dipartimento di Fisica, Florence and INFN Sezione di Firenze, Florence, Italy;* [3] *Department of Physics, University of Surrey, Guildford, UK;* [4] *IRFU, CEA Saclay, Université Paris-Saclay, France;* [5] *University of Guelph, Guelph, Canada;* [6] *Heavy Ion Laboratory, University of Warsaw, Poland;* [7] *INFN, Laboratori Nazionali di Legnaro, Legnaro (Padova), Italy;* [8] *INFN Sezione di Milano, Milano, Italy;* [9] *Università degli Studi di Padova, Padova, Italy;* [10] *IFJ-PAN, Kraków, Poland;* [11] *IJCLab, Université Paris-Saclay, France*

October 31, 2022 - a few days after the 22.18 run