PROBING THE ISOSPIN MIXING IN THE ^{72}Kr COMPOUND NUCLEUS VIA GDR γ DECAY

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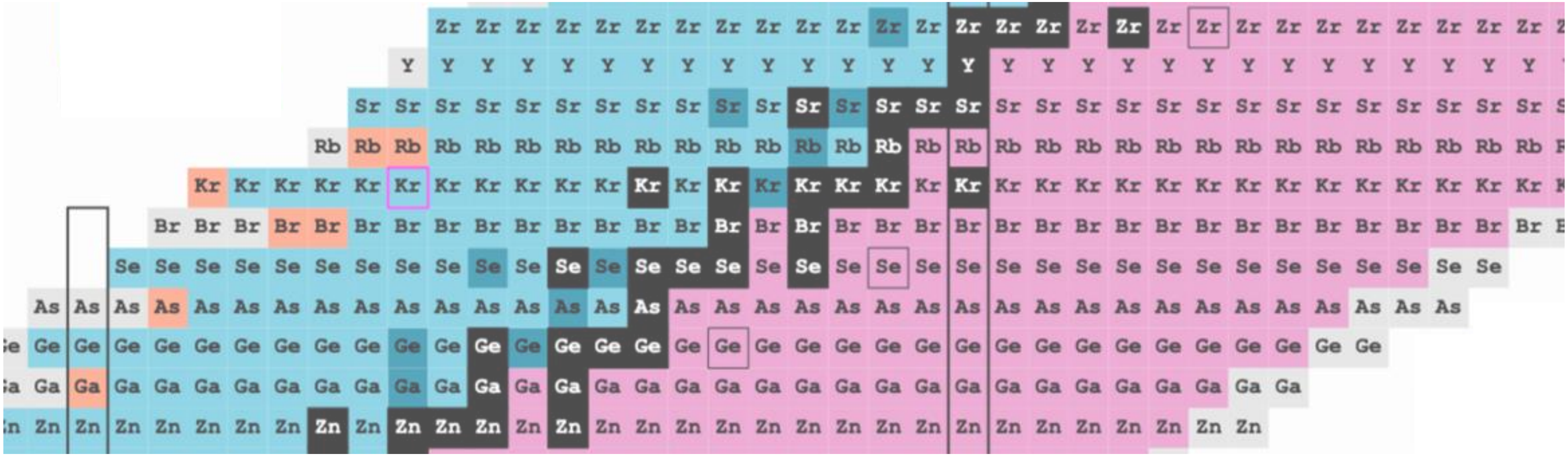
European Nuclear Physics Conference 2025

OUTLINE

- Motivations
  - Isospin mixing
  - Why ^{72}Kr?
- Experimental Technique & Setup
  - Isospin mixing via GDR
- Results
  - The isospin mixing value α^2 and the correction term δ_c
- Summary & Prespectives



MOTIVATIONS

^{72}Kr AT LOWEST POSSIBLE TEMPERATURE

ISOSPIN SYMMETRY

Isospin symmetry plays a key role in nuclear structure and nuclear nuclear reaction.

🔴 $|p\rangle \equiv |I = \frac{1}{2}, I_z = +\frac{1}{2}\rangle$ 🔵 $|n\rangle \equiv |I = \frac{1}{2}, I_z = -\frac{1}{2}\rangle$

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The Coulomb interaction (weaker than the nuclear interaction) breaks the Isospin symmetry inducing a mixing between state with different Isospin:

$$\alpha^2 = \frac{|\langle I = 1|H_c|I = 0\rangle|^2}{\Delta E^2}$$

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Isospin mixing beyond nuclear structure: The CKM matrix ➡

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

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the **V_{ud}** term is obtained from the ft values of $0^+ \rightarrow 0^+$ superallowed Fermi β transition.

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$(\Delta J = 0, \Delta I = 0, \pi_i, \pi_f = +)$

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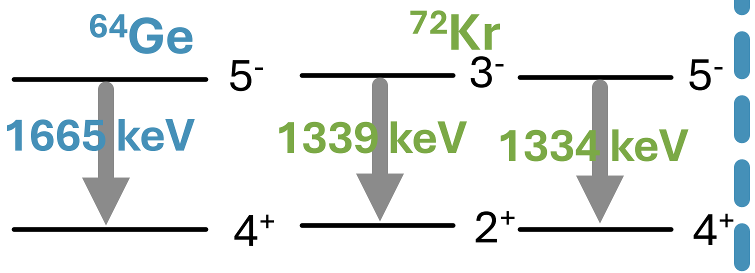

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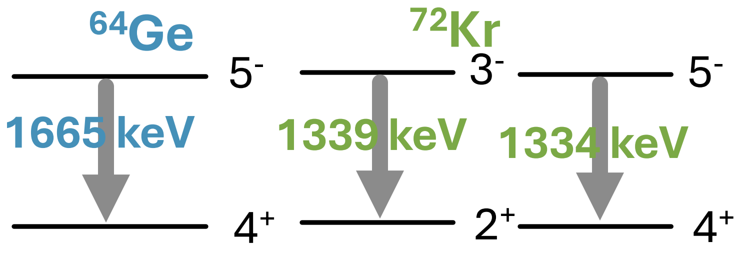

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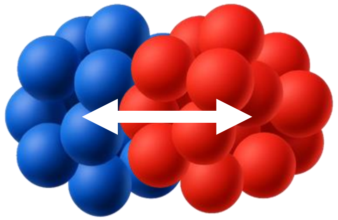

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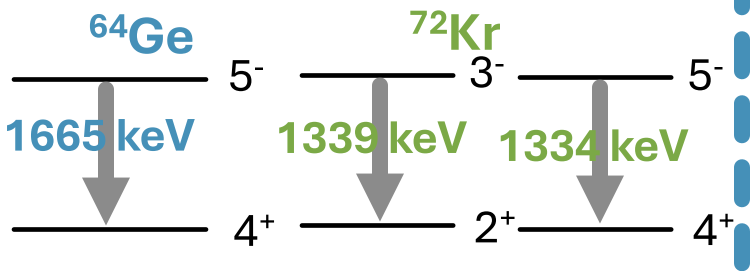

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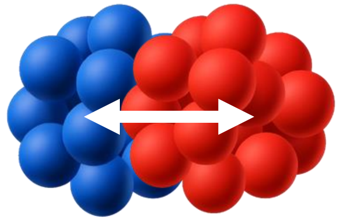

^{72}Kr this work

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- **^{72}Kr** is a N=Z nucleus, produced by fusion-evaporation reactions.
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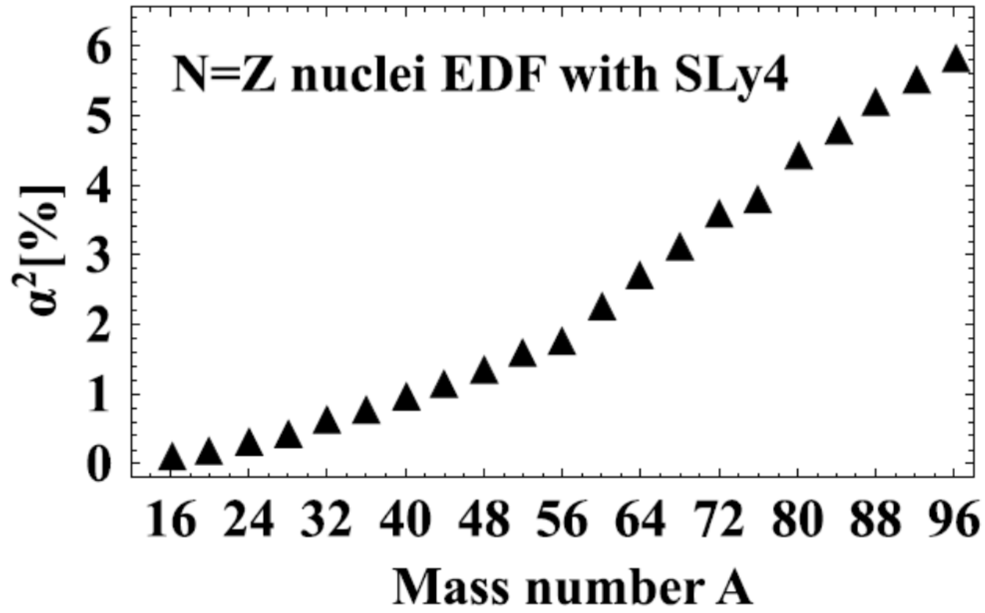

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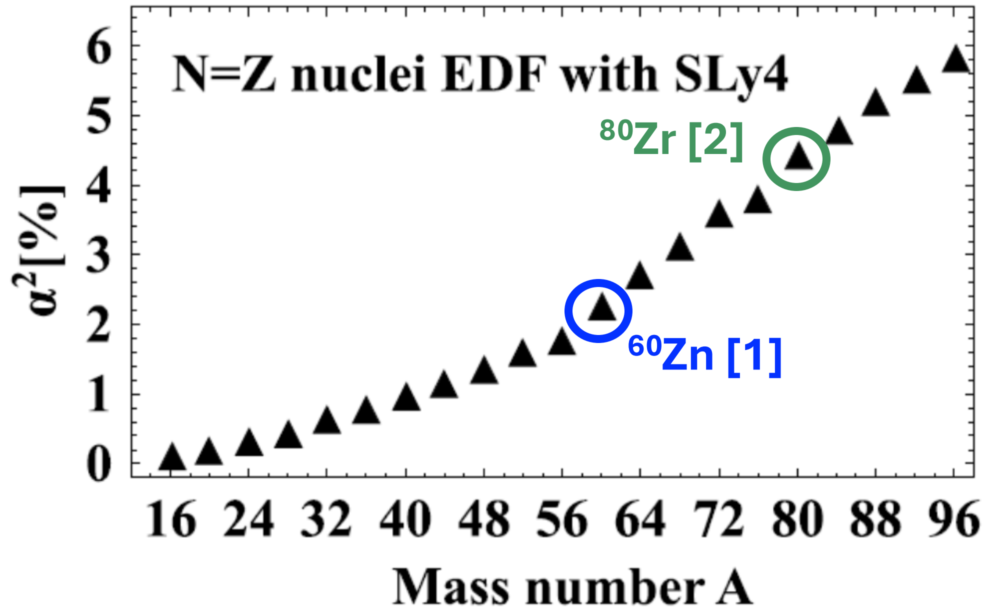

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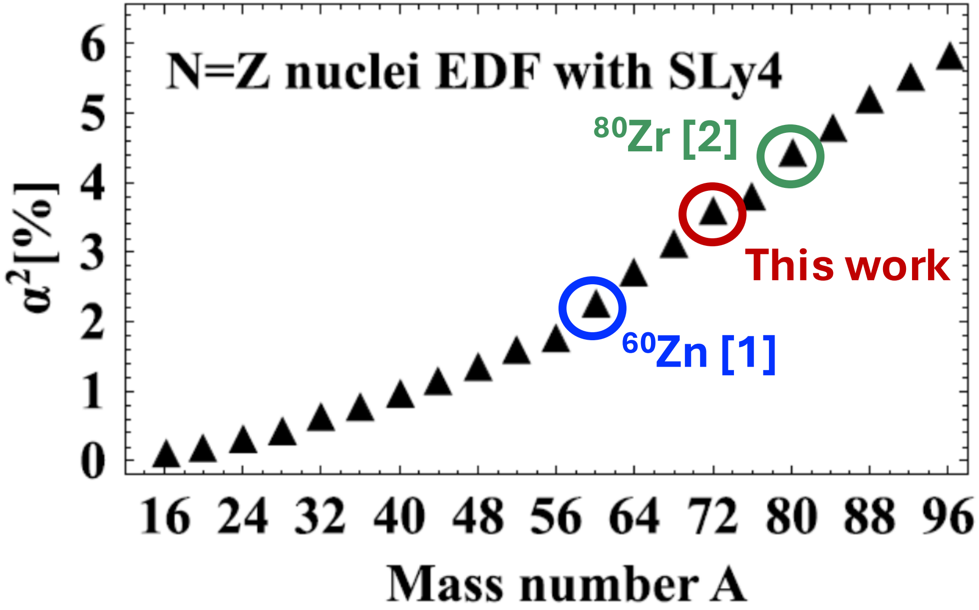

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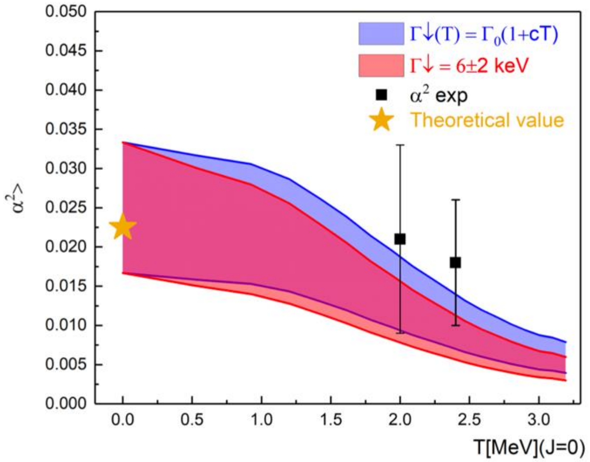

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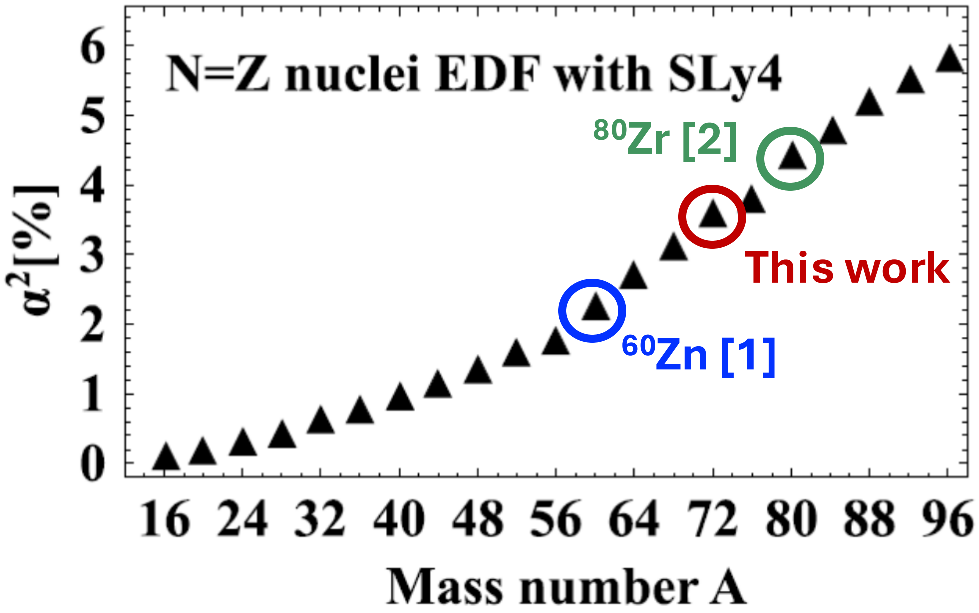

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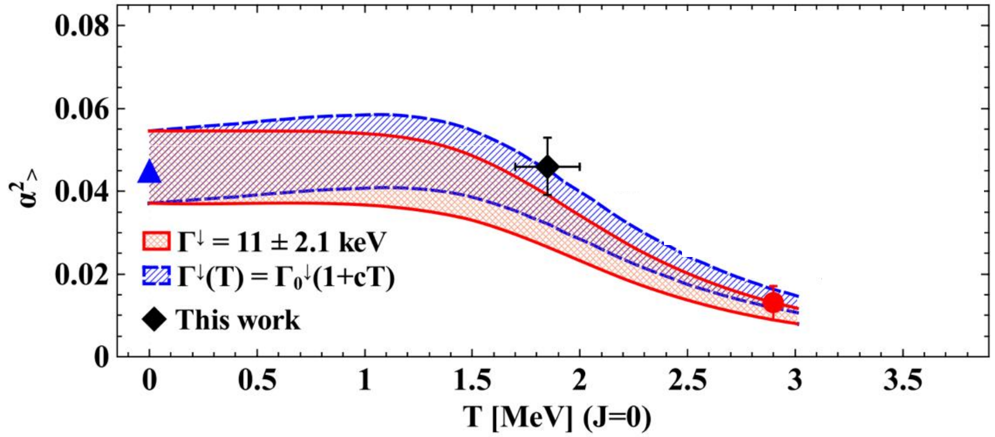

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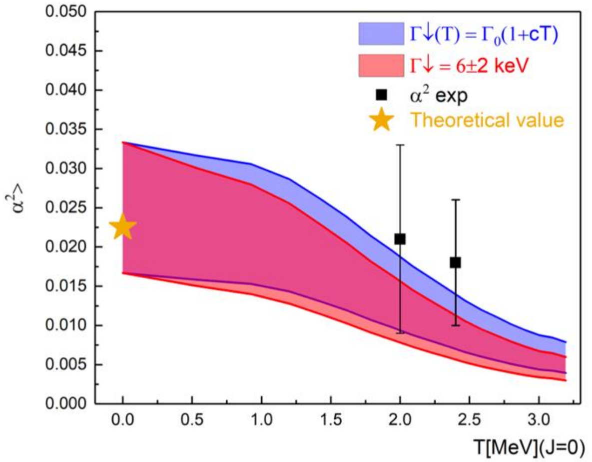

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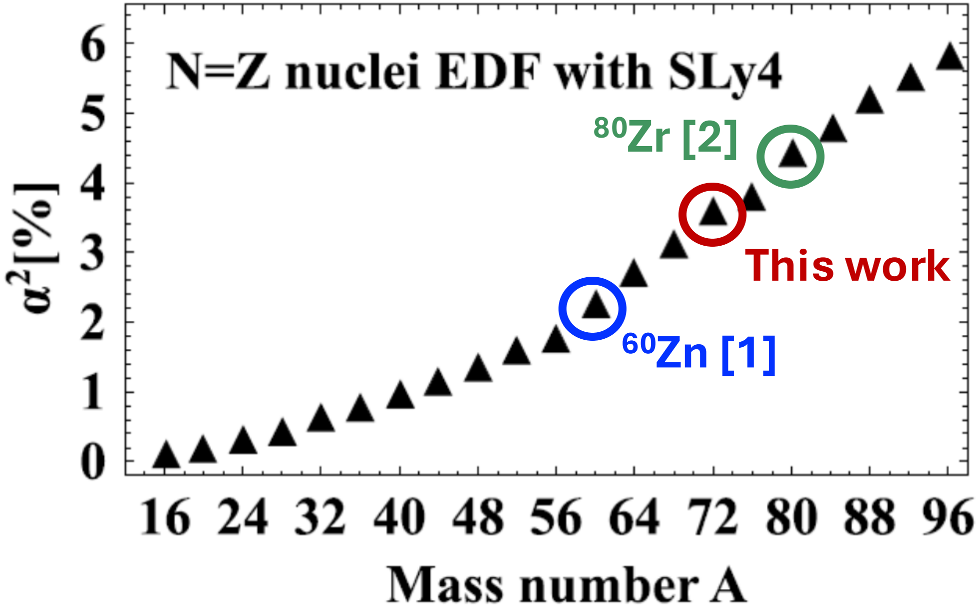

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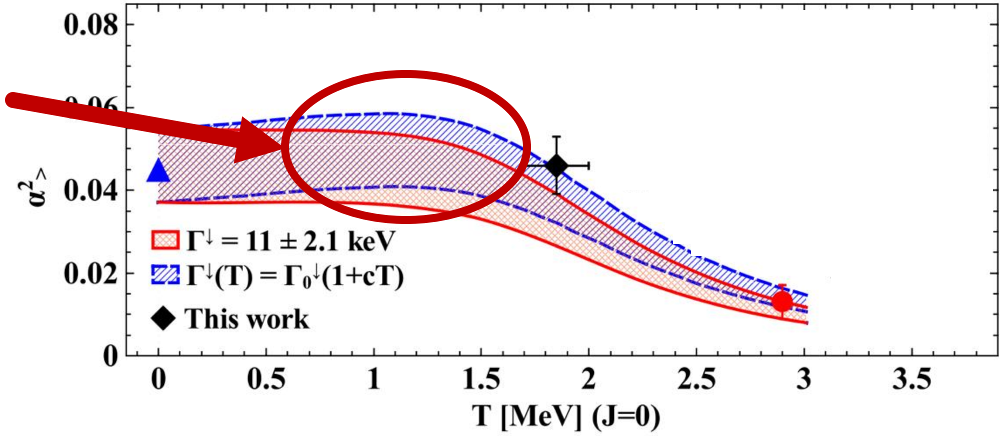
Lowest possible temperature (low cross-section)



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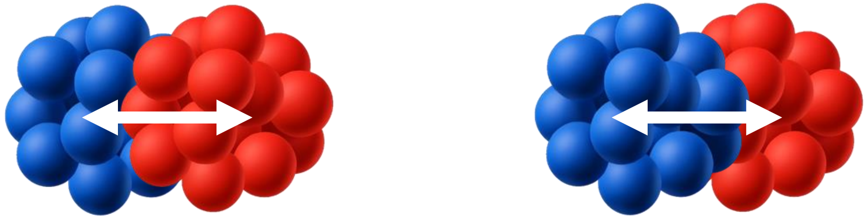
EXPERIMENTAL TECHNIQUE AND SETUP

ISOSPIN MIXING VIA GDR

EXPERIMENTAL TECHNIQUE: GDR (I)



GDR can be described as an oscillation of the protons against the neutrons.

It is and electric $(\Delta S = 0)$ and isovector $(\Delta I = 1)$ transition.

Study of the E1 GRD decay at finite temperature to find the mixing.

To form a compound nucleaus at T>0 we used a fusion-evaporation reaction.

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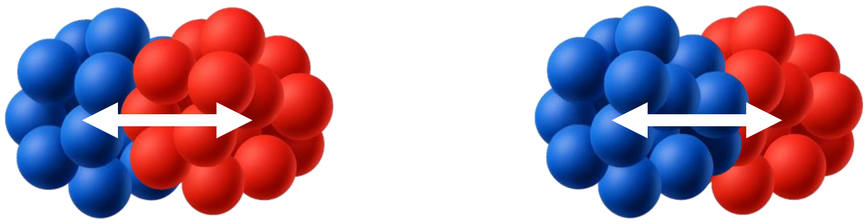

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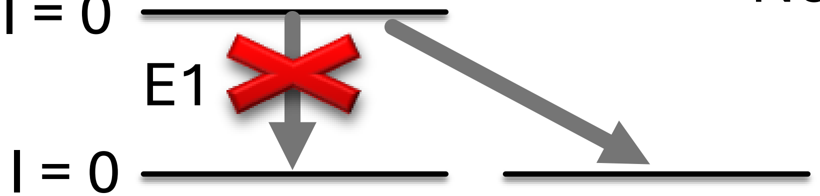

No Mixing

$|A\rangle = |0\rangle$

I = 0

E1

I = 0

I =1

(few states)

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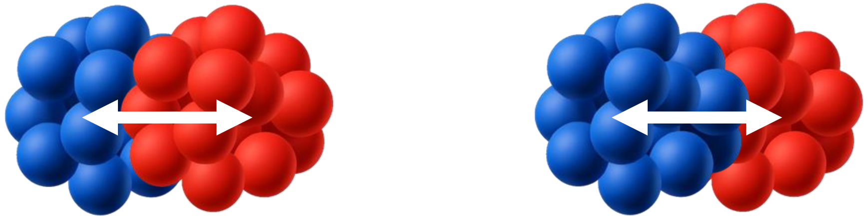

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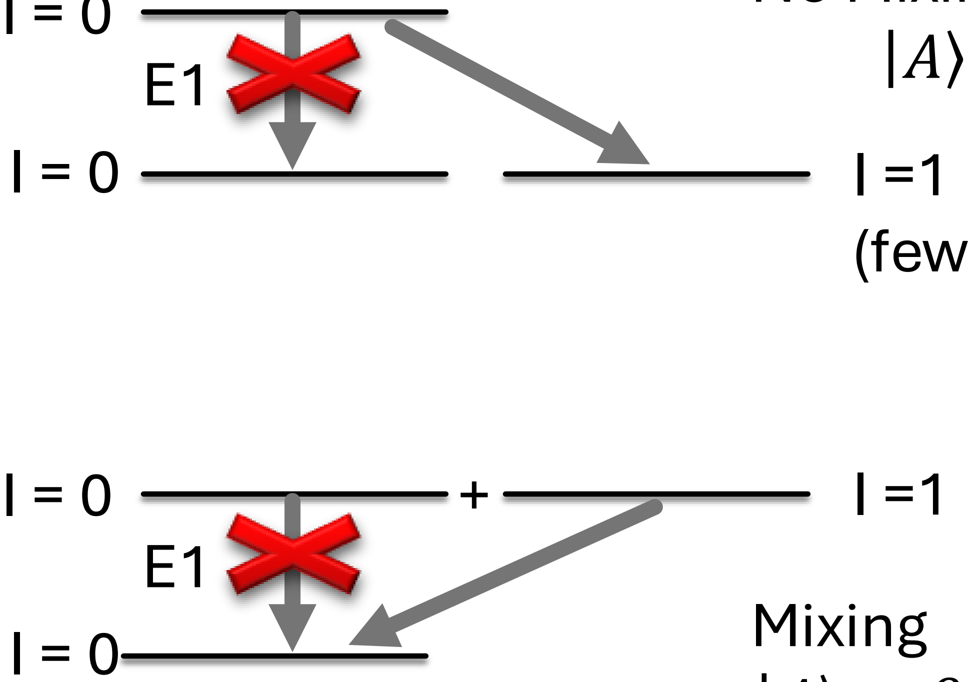

No Mixing

$|A\rangle = |0\rangle$

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Mixing

$|A\rangle = \beta|0\rangle + \alpha|1\rangle$

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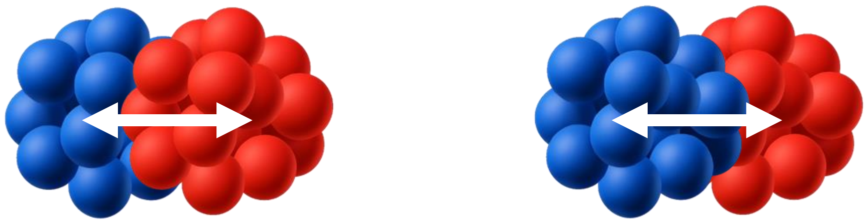

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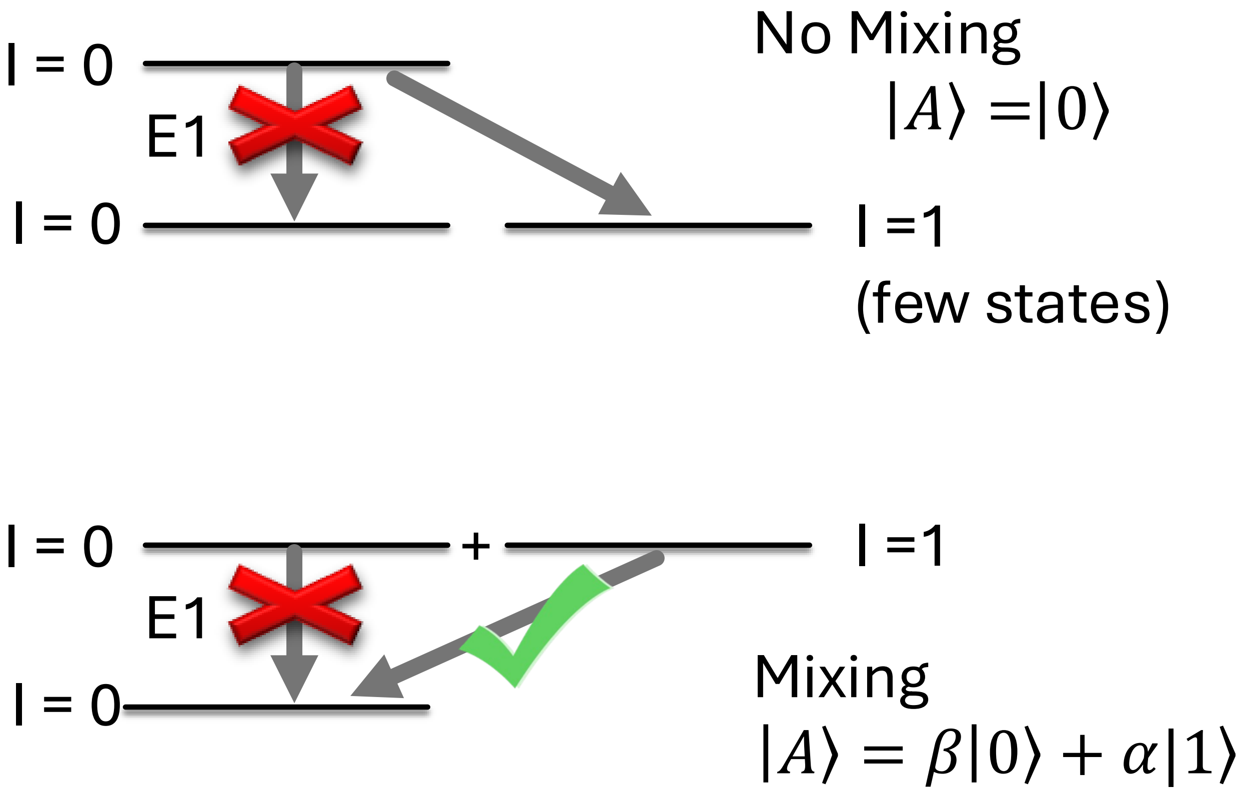

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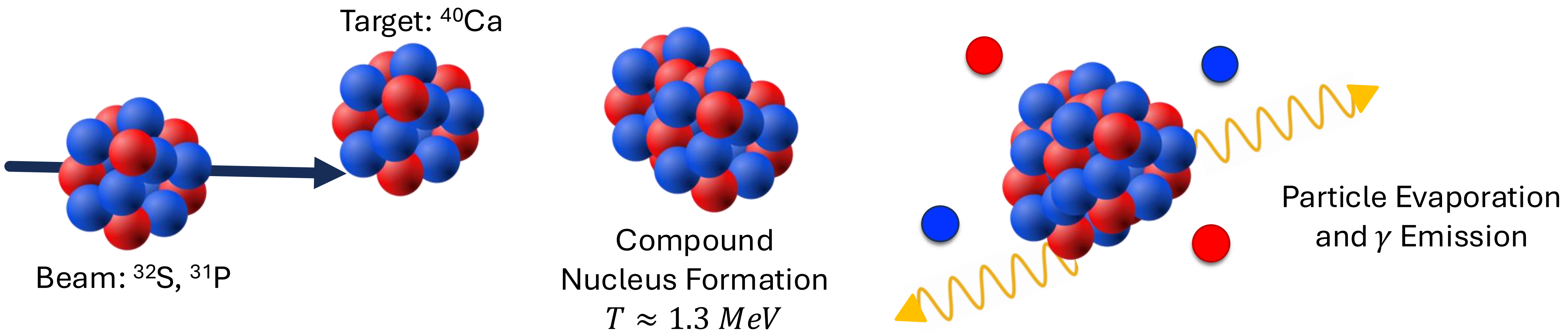


$I = 0$ compound nucleus reaction:

$$^{32}S + {}^{40}Ca \rightarrow {}^{72}Kr^{\,*}$$

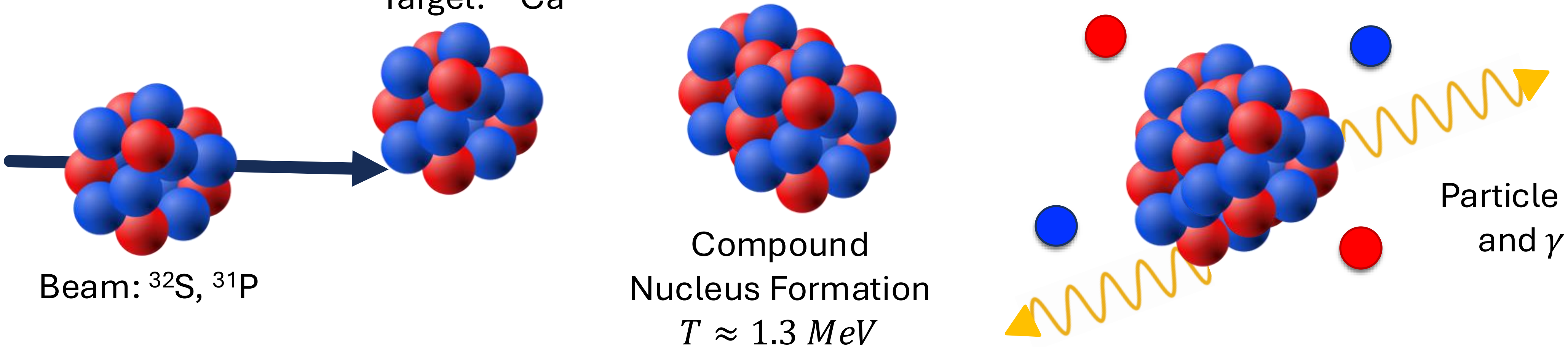
The observed E1 strenght is a signature of the mixing.

$I \neq 0$ compound nucleus reaction:

$$^{31}P + {}^{40}Ca \rightarrow {}^{71}Br^{\,*}$$

Full mixing. No E1 strength reduction is expected.

EXPERIMENTAL TECHNIQUE: GDR (II)



Target: ^{40}Ca

Beam: ^{32}S, ^{31}P

Compound Nucleus Formation
$T \approx 1.3\ MeV$

Particle Evaporation and γ Emission

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GDR manifest itself as E1 Strenght → GDR is a probe of the isospin mixing

PREVIOUS EXPERIMENTS

Nucleus	Temperature	Setup
^{80}Zr	2.8 MeV	HECTOR – GARFIELD [1]
^{80}Zr	1.8 MeV	AGATA –HECTOR^{+} [2]
^{60}Zn	2.0 MeV	GALILEO – 3’’x3’’ LaBr$_3$:Ce [3]
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The new experiment: Isospin Mixing in ^{72}Kr at the lowest possible temperature.

- In the flat part of the isospin mixing as a function of T
- Low cross-section

[1] A. Corsi et al., PRC 84, 041304(R) (2011)

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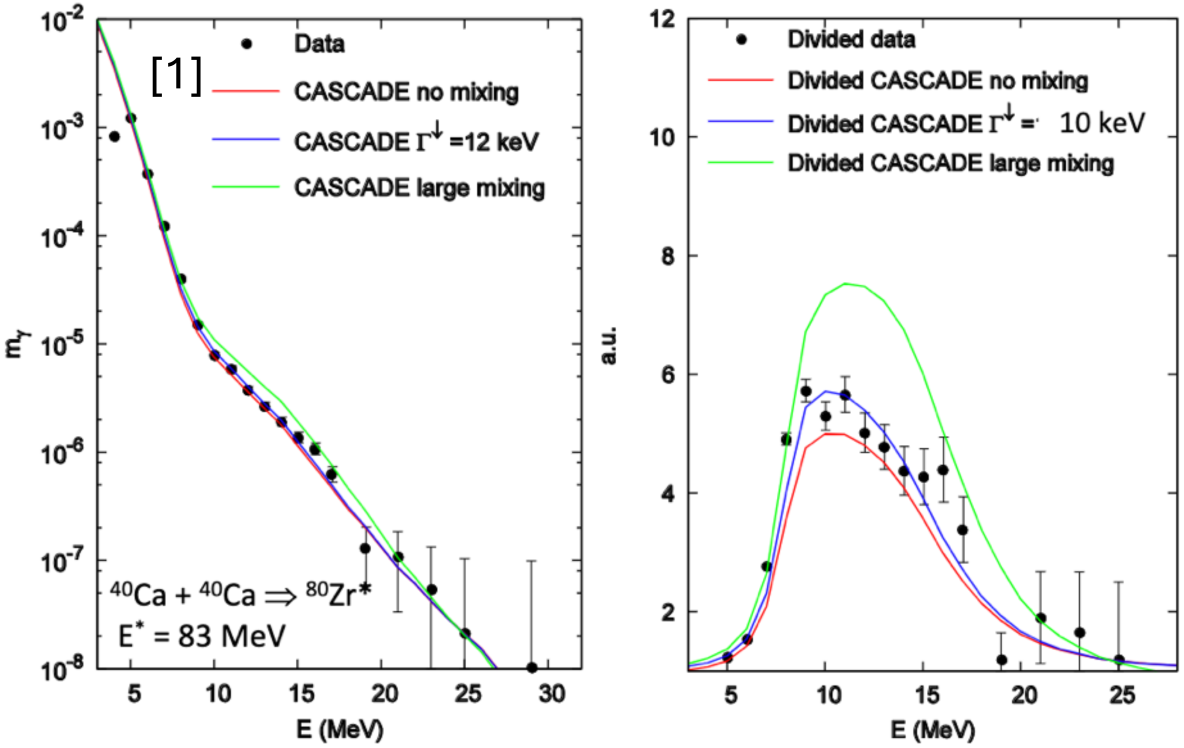

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EXPERIMENTAL SETUP

ELIFANT-GG Array:

High-energy γ rays:

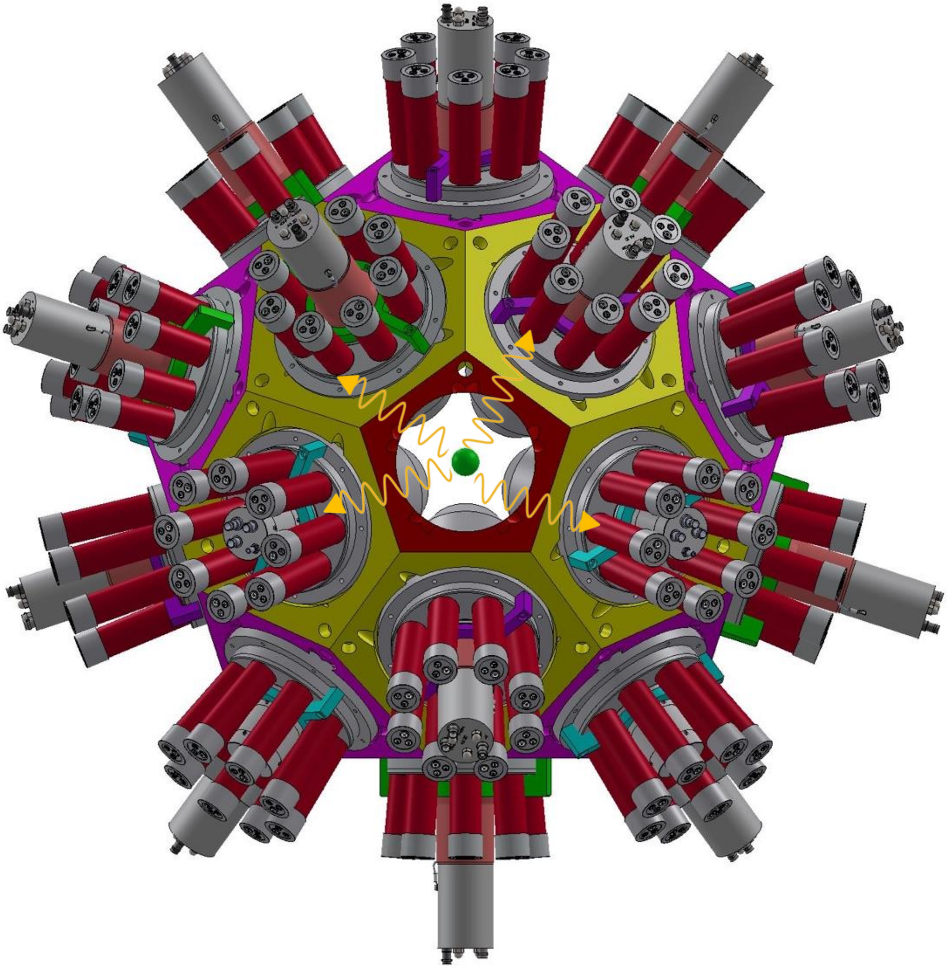
21 Bromide Scintillator Detector Array: 11 3''x3'' $LaBr_3$:Ce + 10 $CeBr_3$ (3''x3'') (AC schield)

Fusion-evaporation residues (low-energy γ rays):

4 AC-shield HPGe detectors

IFIN-HH

eli nuclear physics



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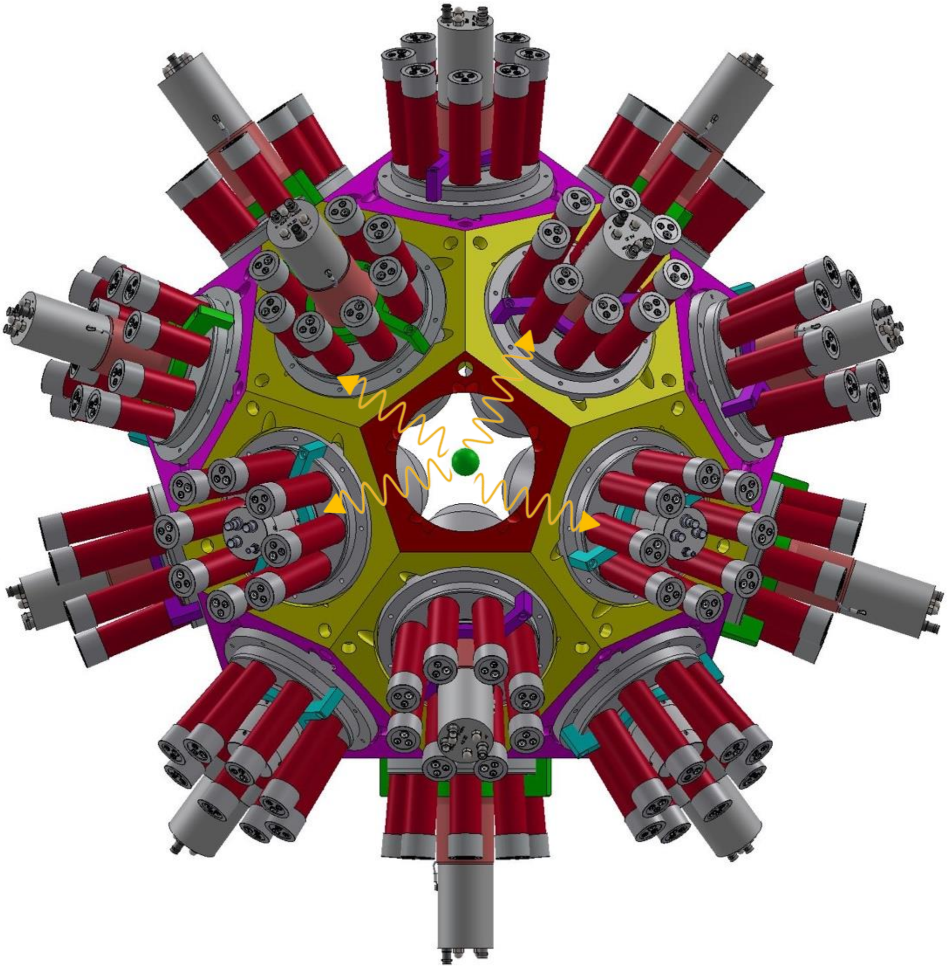

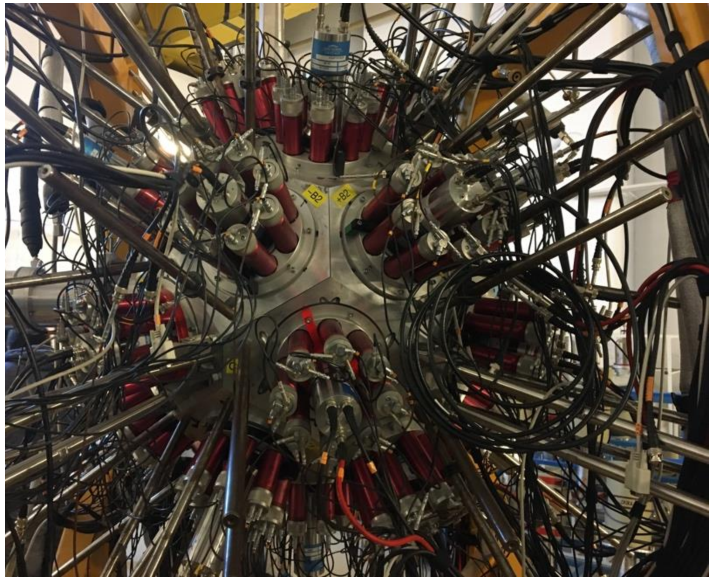

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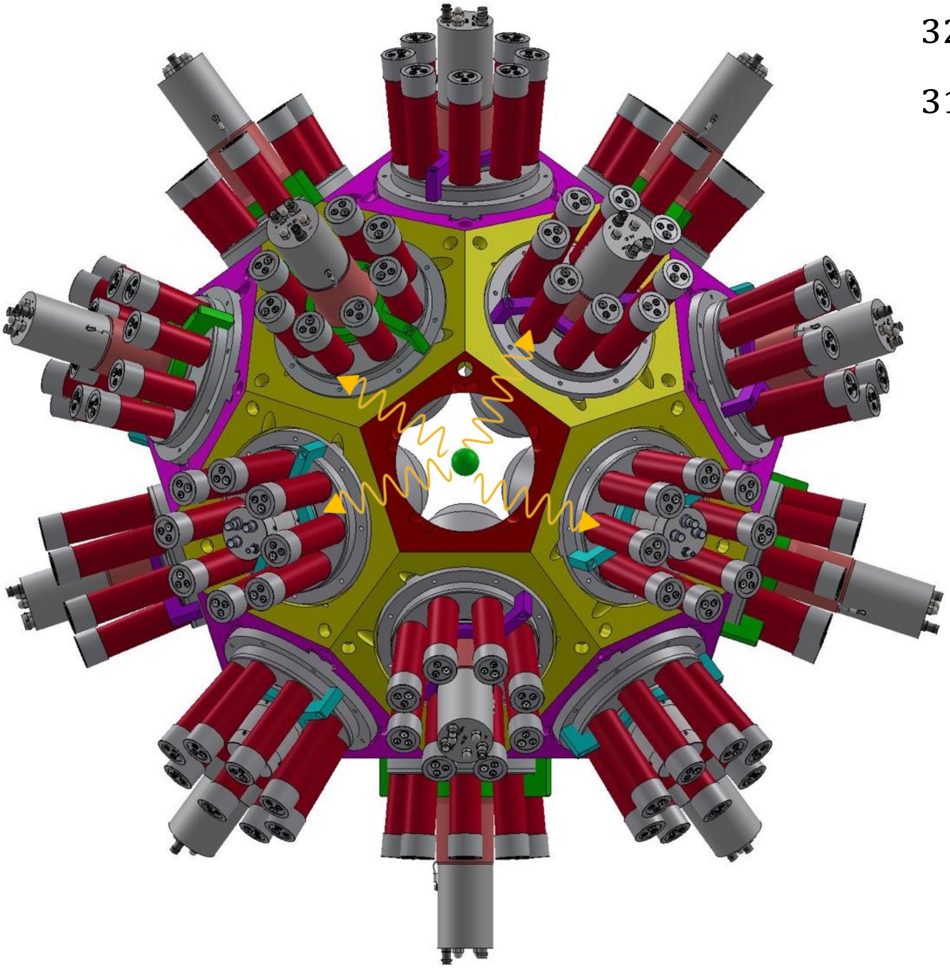
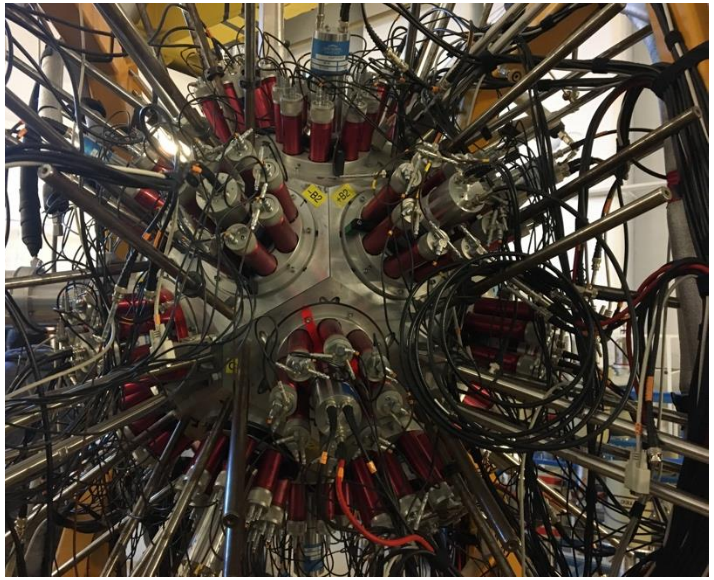
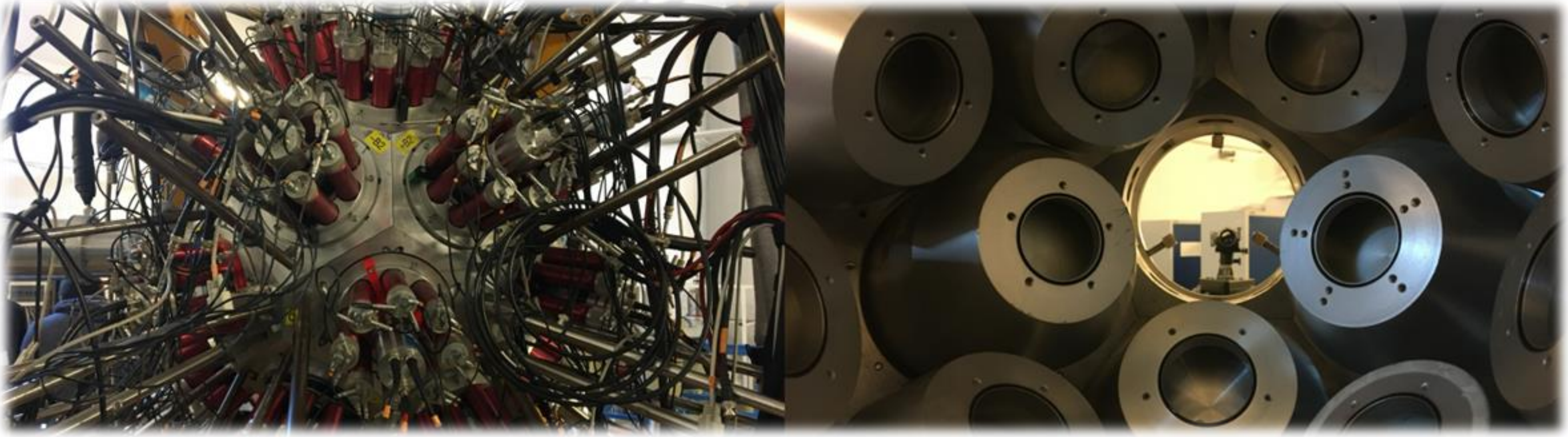


$$^{32}S + {}^{40}Ca \rightarrow {}^{72}Kr^{*} \text{ @ 90 MeV}$$
$$^{31}P + {}^{40}Ca \rightarrow {}^{71}Br^{*} \text{ @ 82 MeV}$$

Low cross-section

High efficiency





RESULTS

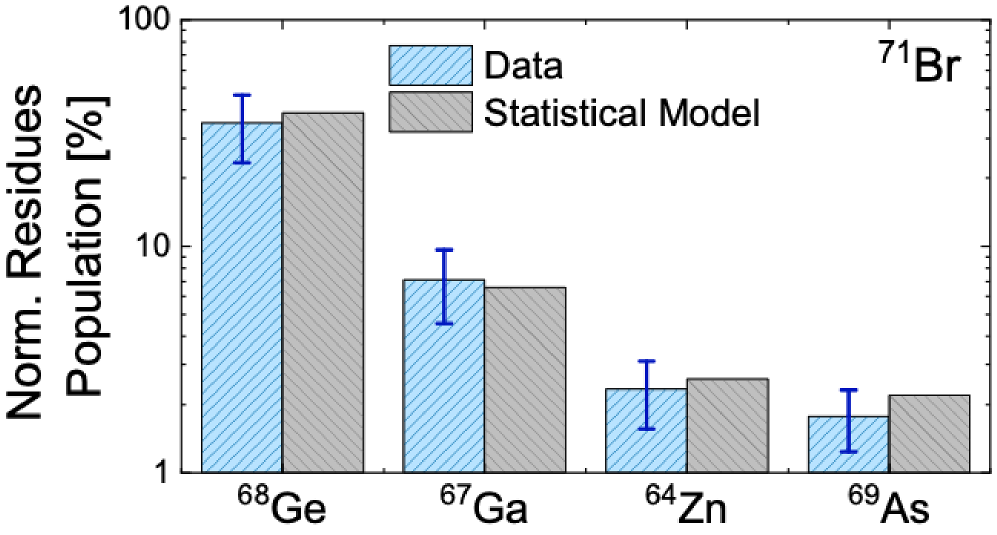
ISOSPIN MIXING PARAMETRES: α^2 & δ_c

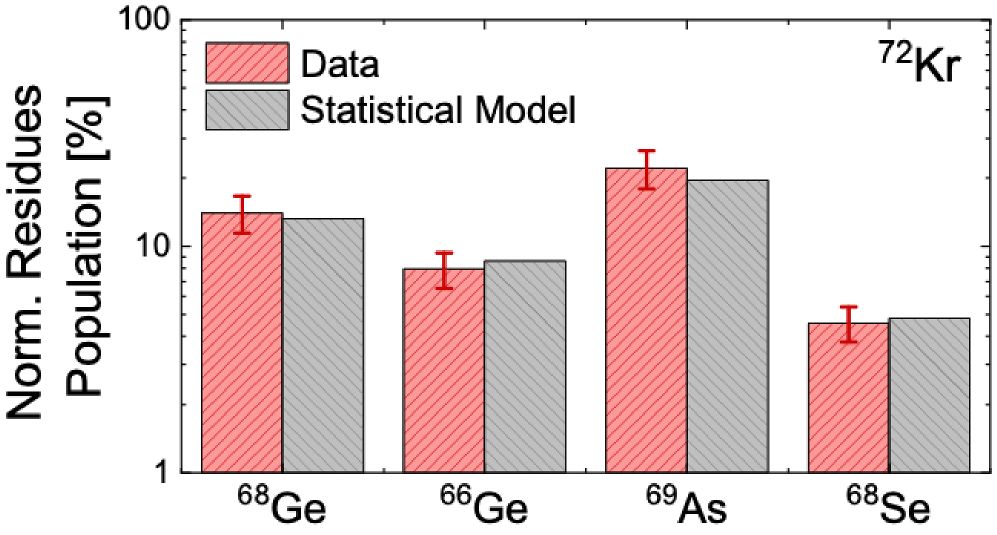
RESULTS: EVAPORATION RESIDUES

Fusion-evaporation residues (low-energy γ rays): 4 AC-shield HPGe detectors

Experimental population of the residues compared with the statistical model prediction.

The most populated residues are reproduced within the error bars.





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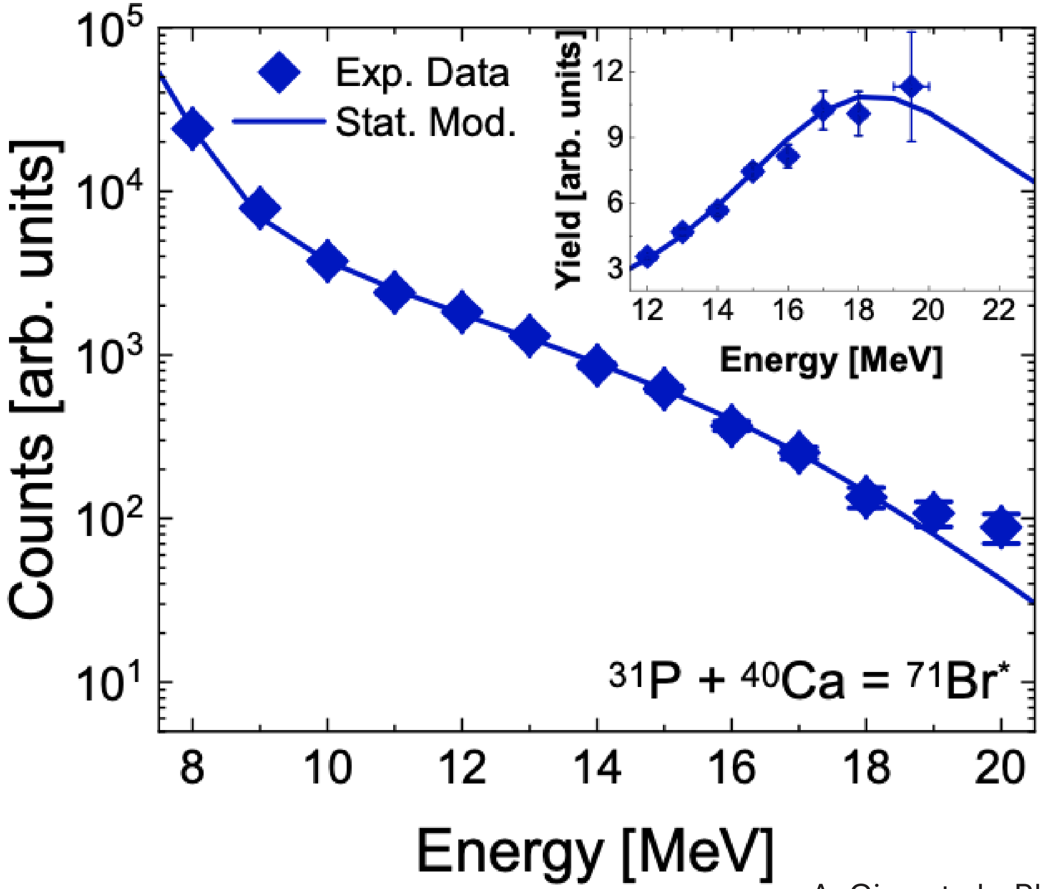
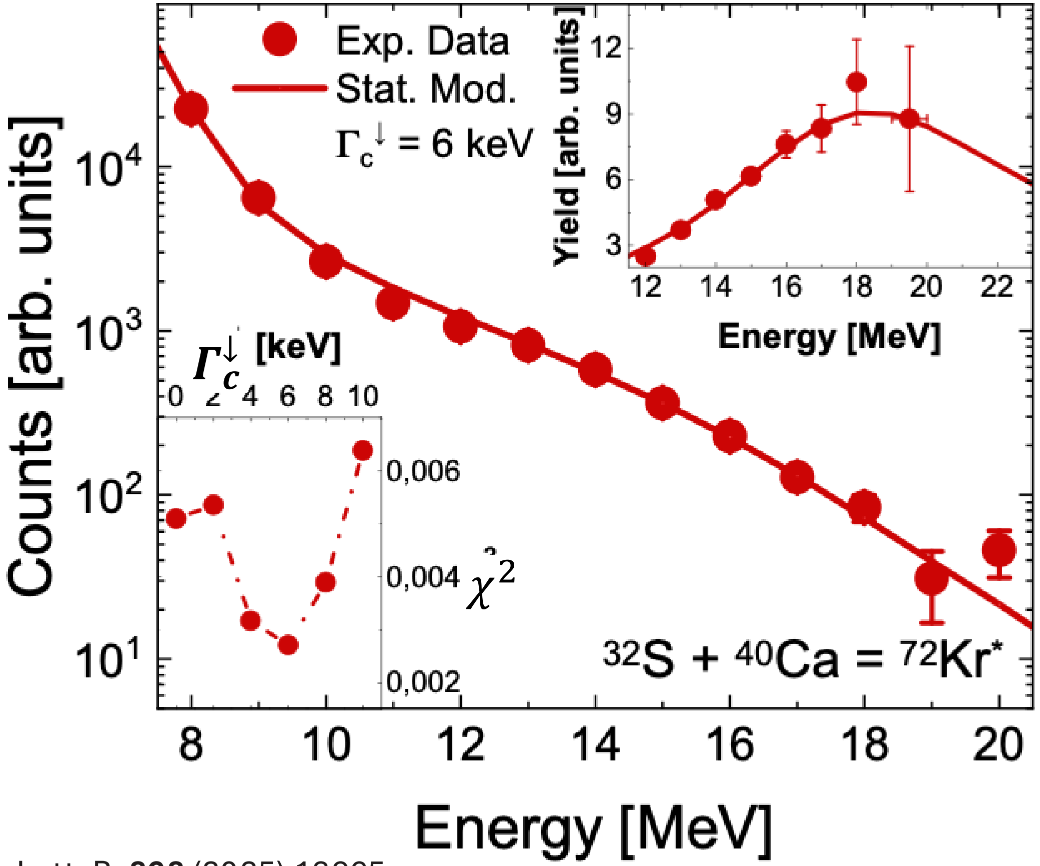
RESULTS: HIGH-ENRGY γ-RAY SPECTRA



$I = 0$ – Mixing $\Gamma_c^{\downarrow} = 6\ keV$



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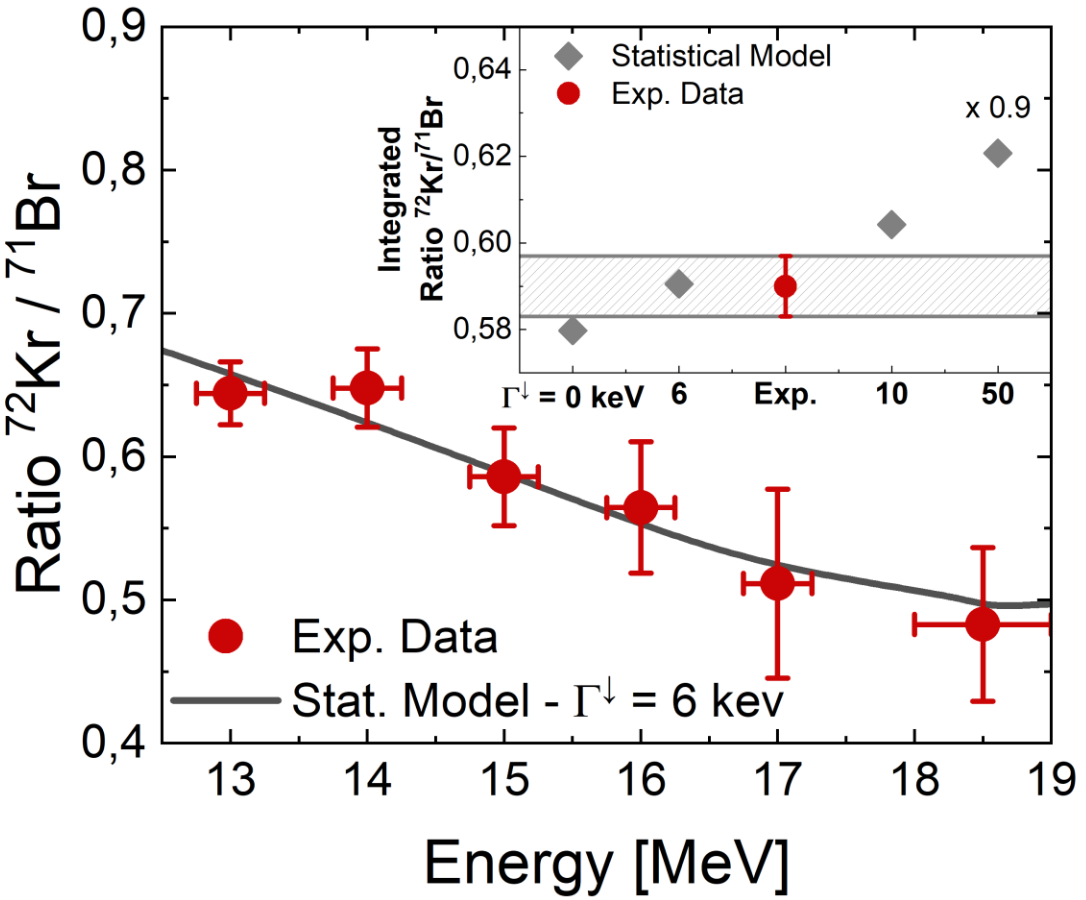
RESULTS: MIXING ESTIMATION

Statistical model with different values of $\Gamma_c^{\downarrow}$: 0 (no mixing), 6, 10 and 50 keV (full mixing).



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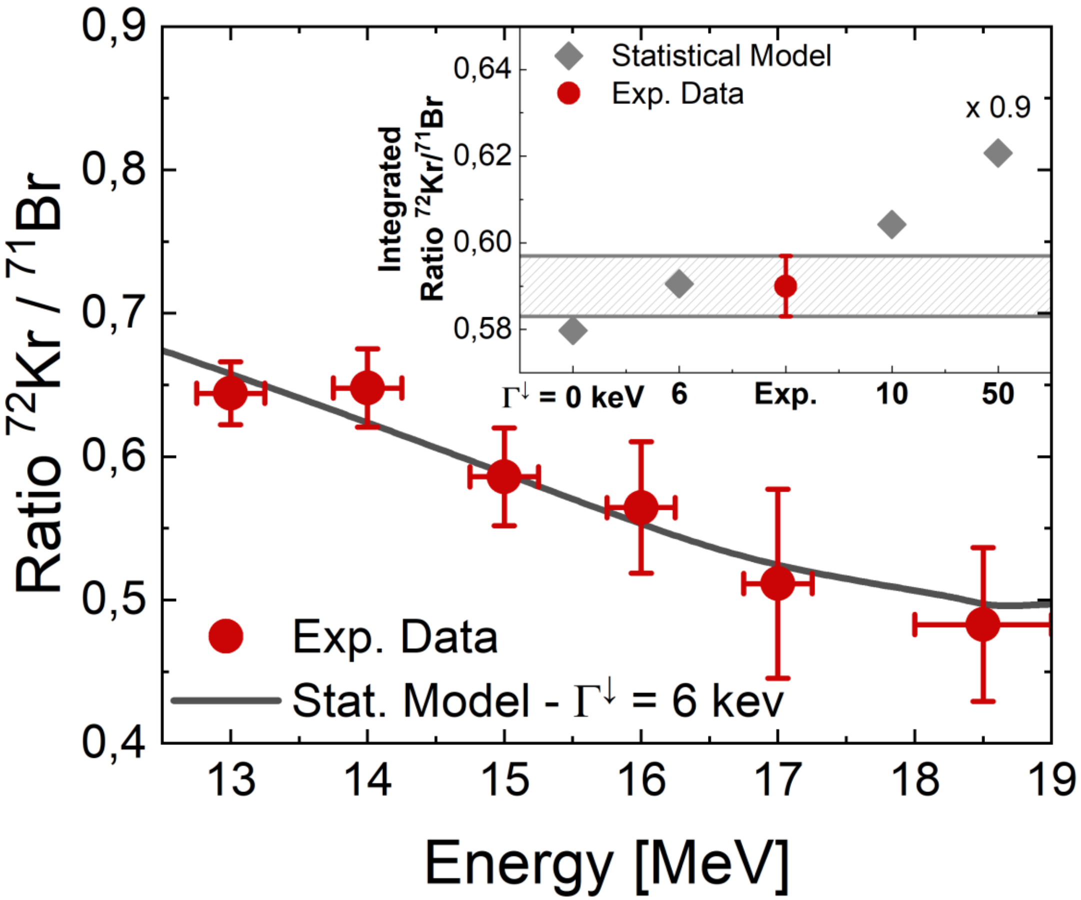
RESULTS: MIXING ESTIMATION

Statistical model with different values of $\Gamma_c^{\downarrow}$: 0 (no mixing), 6, 10 and 50 keV (full mixing).

Integrated Ratio ^{72}Kr and ^{71}Br from 13 MeV to 18 MeV:

- Experimental data: $\mathbf{0.590 \pm 0.007}$
- Statistical model $\Gamma_c^{\downarrow} = 6\ keV$: $\mathbf{0.591}$



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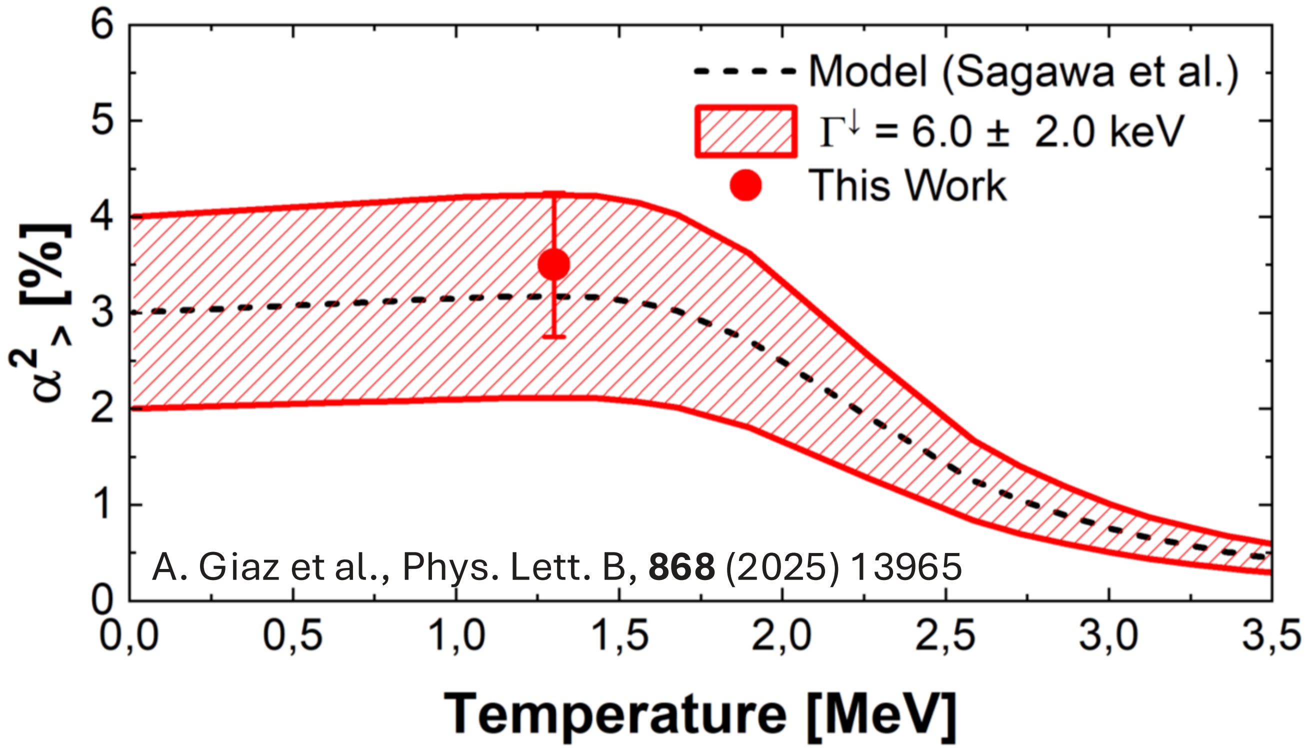
RESULTS: α^2 MIXING PARAMETER (I)

From T>0 to T=0

α^2 trend as a function of temperature:

$$\alpha^2(T) = \frac{1}{I_0+1}\frac{\Gamma^{\downarrow}_{IAS}}{\Gamma_{CN}(T)+\Gamma^{(IAS)}_{IVM}}$$



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[1] G.C.H. Sagawa, P.F. Bortignon, Phys. Lett. B, 444, (1998), 1-6

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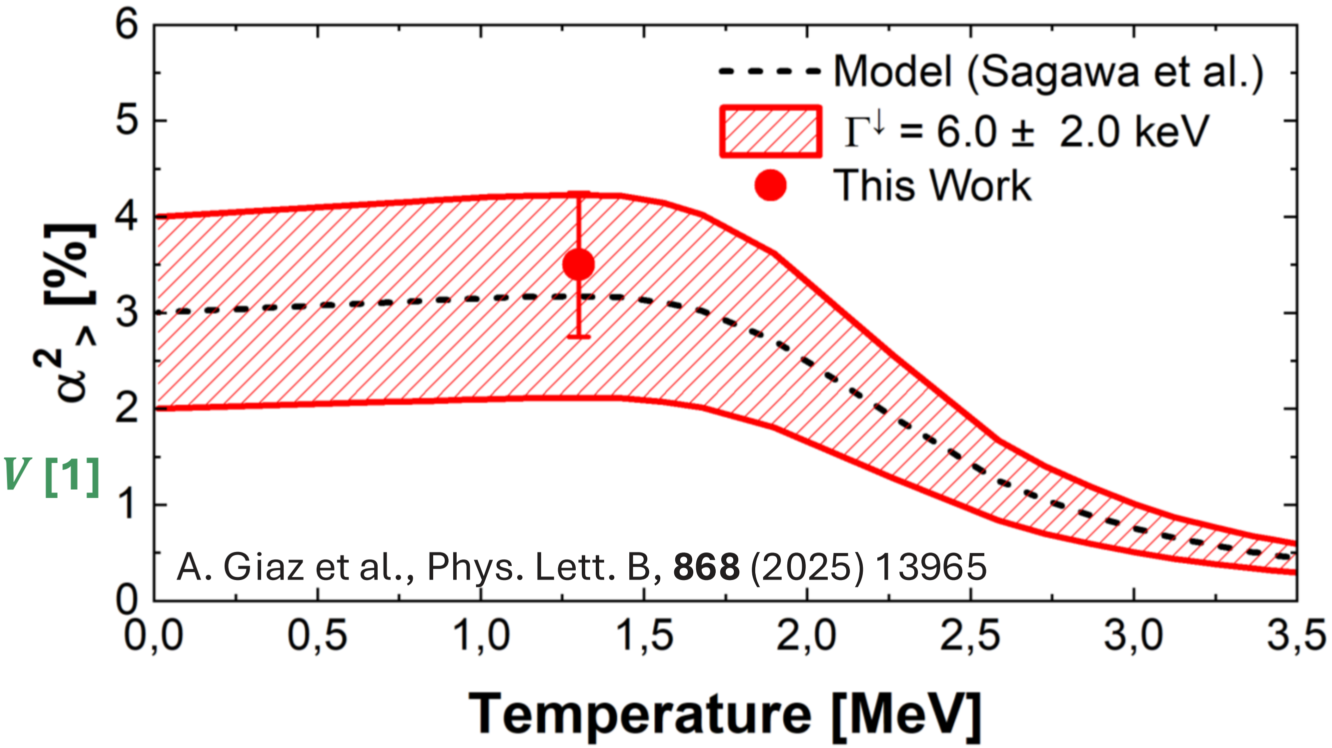
200 keV [1]

- $\Gamma^{(IAS)}_{IVM}$ width of IVM resonance at excitation energy of IAS



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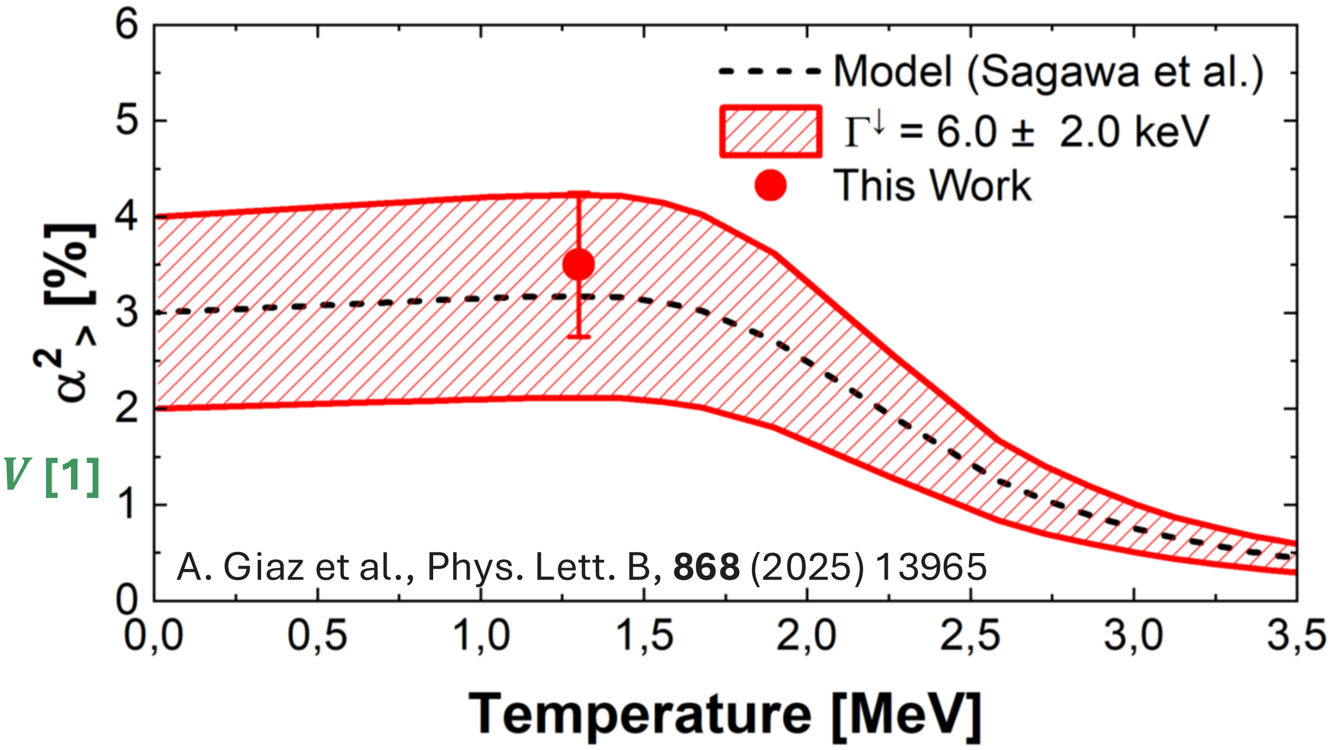
- $\Gamma^{(IAS)}_{IVM}$ width of IVM resonance at excitation energy of IAS
- $\Gamma_{CN}(T)$ is the compound nucleus decay width



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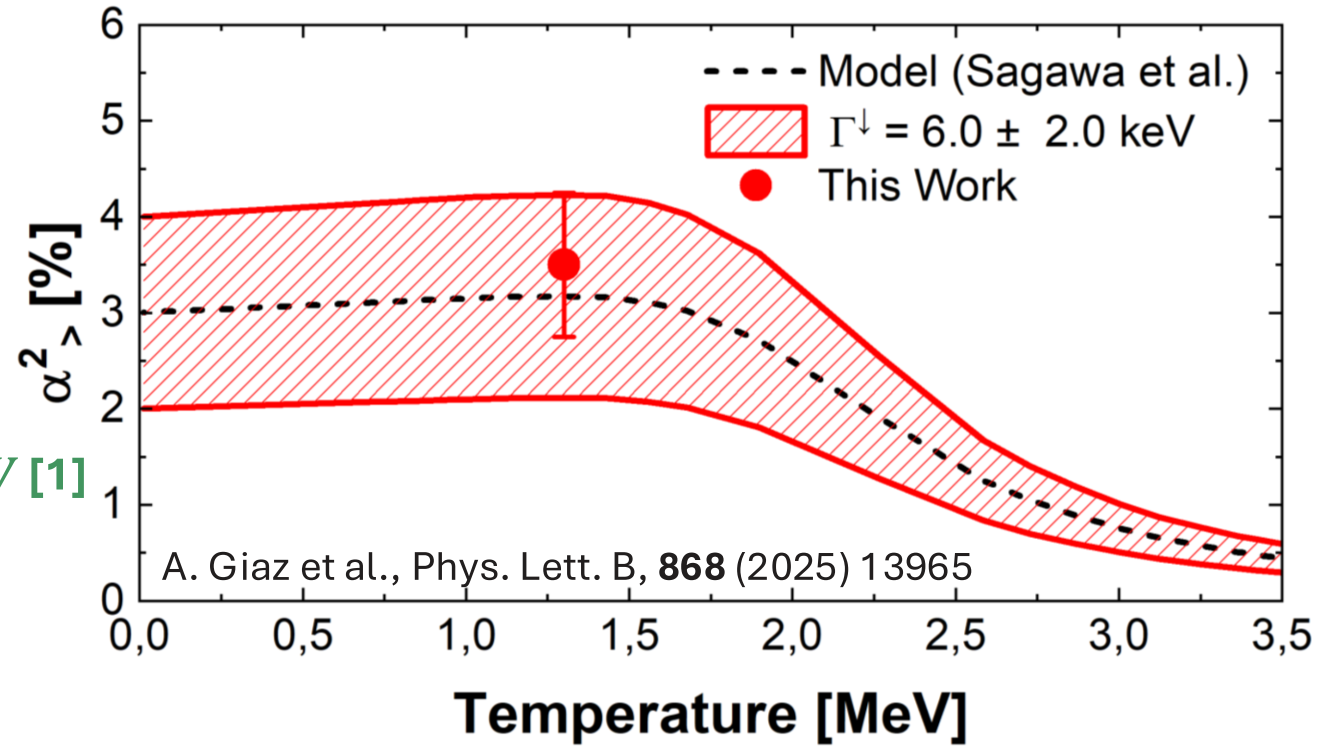
α^2 trend as a function of temperature:

$$\alpha^2(T) = \frac{1}{I_0 + 1}\frac{\overset{\mathbf{6.0 \pm 2.0\ keV}}{\Gamma^{\downarrow}_{IAS}}}{\underset{\text{From Stat. Model}}{\Gamma_{CN}(T)} + \underset{\mathbf{200\ keV}\ [1]}{\Gamma^{(IAS)}_{IVM}}}$$

- $\Gamma^{(IAS)}_{IVM}$ width of IVM resonance at excitation energy of IAS
- $\Gamma_{CN}(T)$ is the compound nucleus decay width
- $\Gamma^{\downarrow}_{IAS}$ is $\Gamma^{\downarrow}_{c}$



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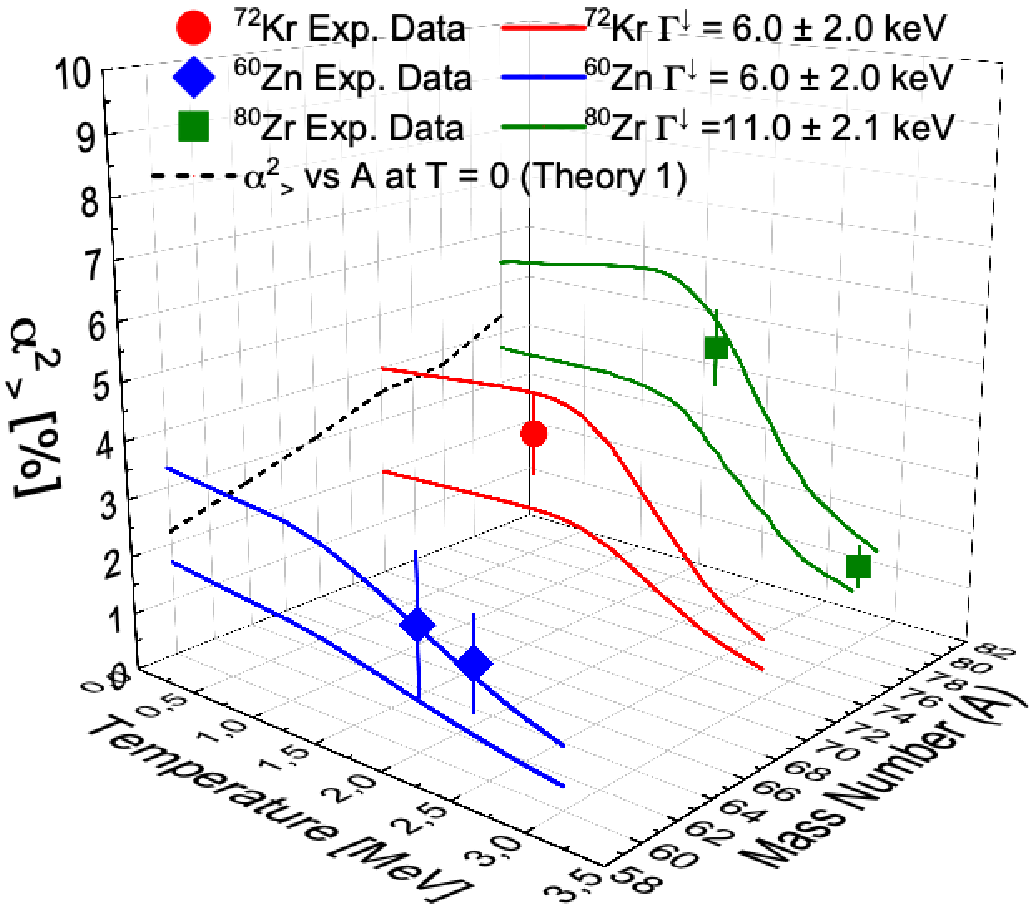
RESULTS: α^2 MIXING PARAMETER (II)



From finite temperature to zero temperature:

- **^{60}Zn**: $(2.5 \pm 0.8)\ \%\ @\ T = 0$ [1]
- **^{80}Zr**: $(4.6 \pm 0.9)\ \%\ @\ T = 0$ [2]
- **^{72}Kr**: $(3.0 \pm 0.8)\ \%\ @\ T = 0$ and
  $(3.5 \pm 0.8)\ \%\ @\ T = 1.3\ MeV$ [3]

[1] G. Gosta et al., Phys. Rev. C **103**, (2021) L041302
[2] S. Ceruti et al., Phys. Rev. Lett. **115**, (2015) 222502
[3] A. Giaz et al., Phys. Lett. B, **868** (2025) 13965

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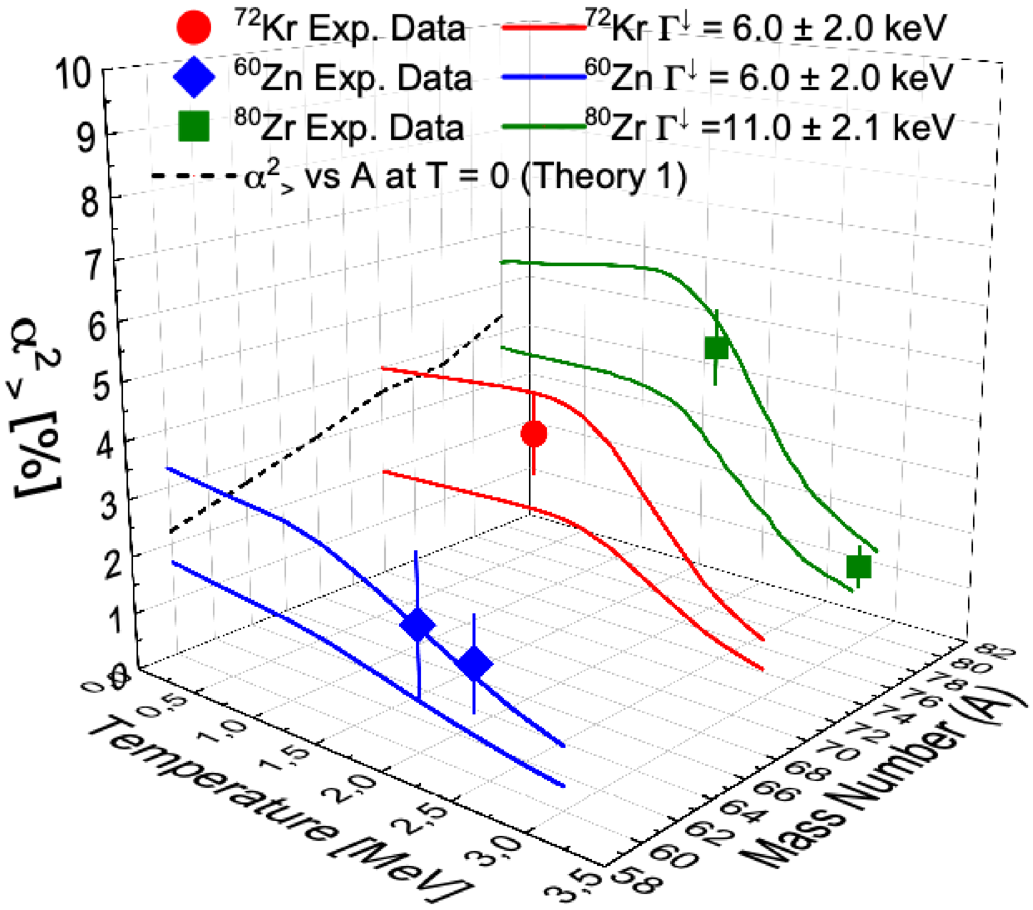

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Mixing Probability α^2 follows the expected trend both as a function of **Mass Number (A)** and **Temperature**

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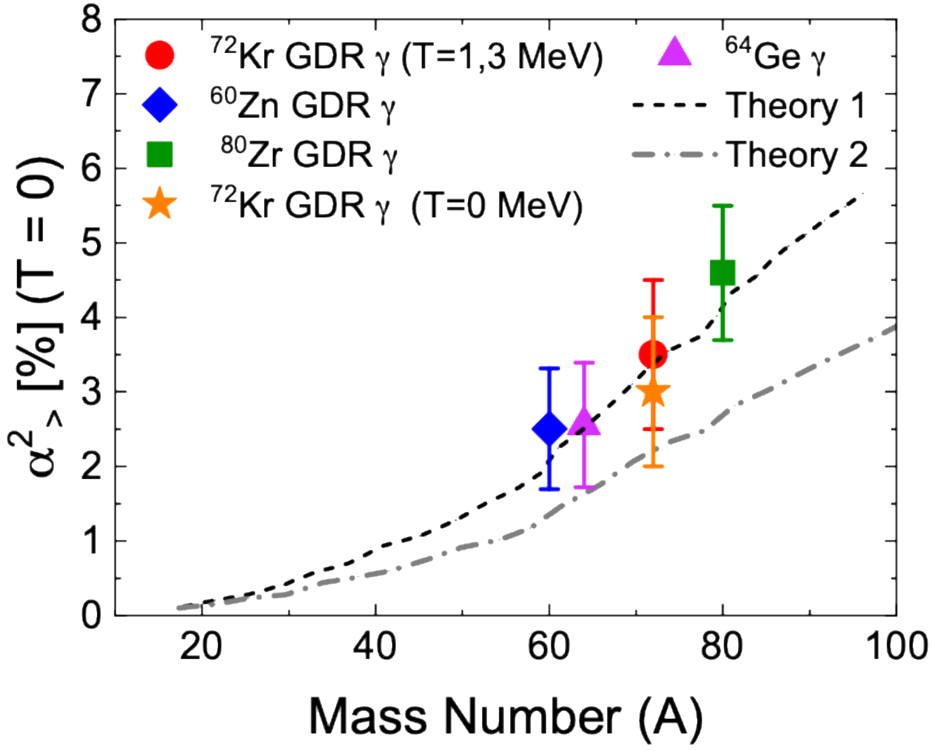
RESULTS: CORRECTION TERM δ_c

From α^2



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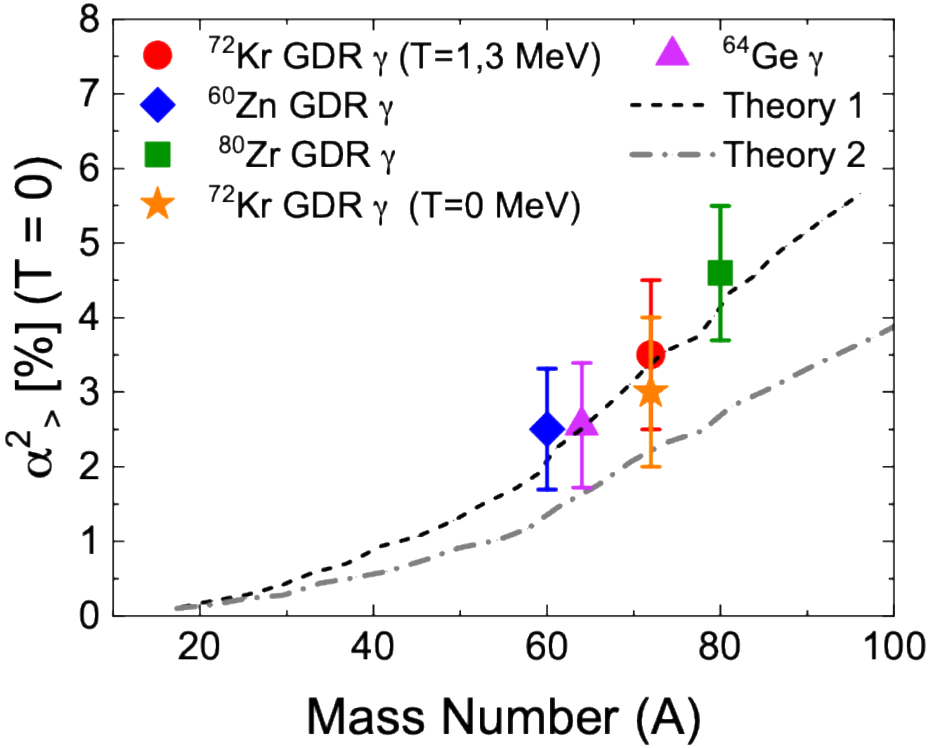
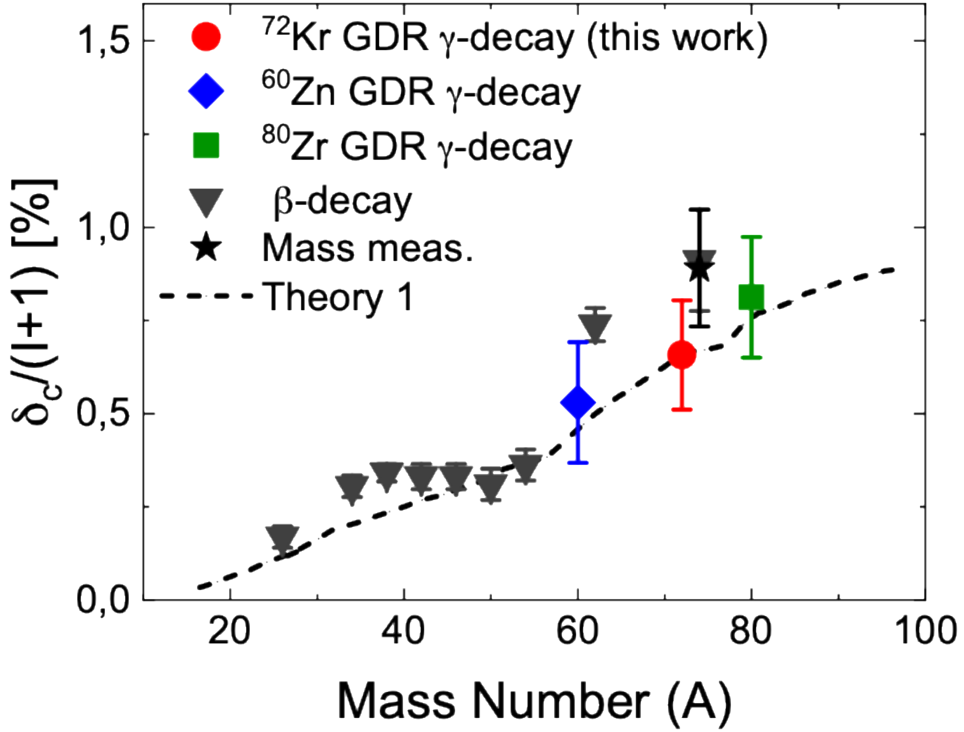


To $\delta_c = 4(I+1)\frac{V_1}{41\xi A^{2/3}}\alpha^2$

$$\delta_c = (0.66 \pm 0.14)\%$$



SUMMARY AND PRESPECTIVES

SUMMARY

- We measure the isospin mixing via GDR in ^{72}Kr at ELIGANT setup at the IFIN-HH Tandem (Bucharest)
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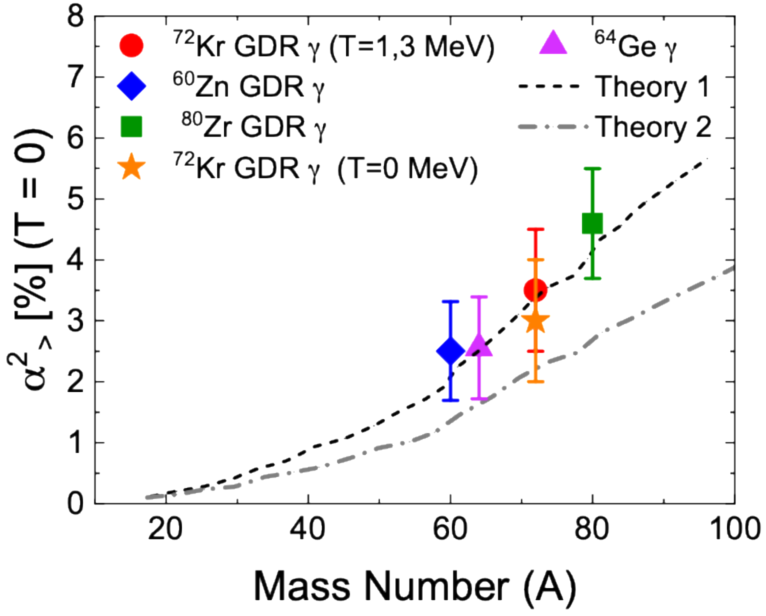

PRESPECTIVES

- Exotic beam to reach N=Z nuclei with A > 80
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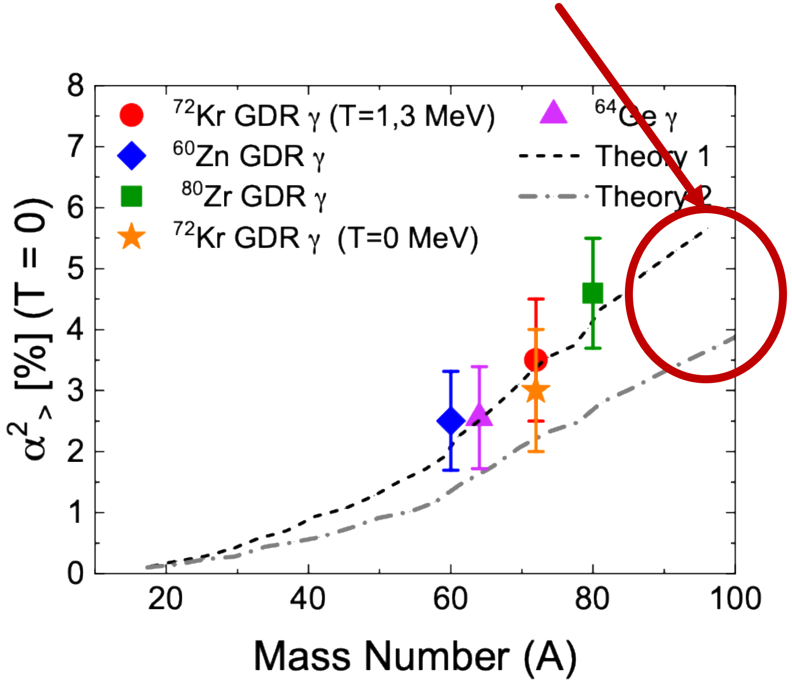

COLLABORATORS

Agnese Giaz[a], Oliver Wieland[a], Angela Bracco[b,a], Franco Camera[b,a], Soichiro Aogaki[c], Dimiter L. Balabanskic, Maria Brezeanu[c], Ruxandra Borcea[d], Marian Boromiza[d], Ion Burducea[e], Stefana Calinescu[d], Adina Coman[d], Paul Constantin[c], Cristian Costache[d], Michał Ciemała[f] , Gheorghe Ciocan[d], Cristina Clisu[d], Fabio C.L. Crespi[b,a], Mihai Cuciuc[c], Anukul Dhal[c], Irina Dinescu[d], Nikolay Djourelov[c], Nicoleta M. Florea[d], Ioana Gheorghe[d], Decebal Iancu[e], Violeta Iancu[c], David M. Kahl[c], Maria Kmiecik[f], Aslı Kuşoğlu[c,g], Razvan Lica[d], Adam Maj[f] , Nicolae M. Mărginean[d], Raluca Mărginean[d], Constantin Mihai[d], Radu E. Mihai[d,h], Bénédicte Million[a], Catalin Neacsu[d], Dragos Nichita[c], Cristina R. Niţă[d], Haridas Pai[c], Alfio D. Pappalardo[c], Teodora Petruse[c], Adrian Rotaru[c], Andreea B. Serban[c], Pär-Anders Söderström[c], Cristophe O. Sotty[d], Anamaria Spătaru[c], Lucian Stan[d], Alexandru N. State[c], Alexandru Stoica[d], Dmitry A. Testov[c], Sebastian Toma[d], Tatiana Tozar[c], Andrei Turturică[d], Gabriel V. Turturică[c], Sorin Ujeniuc[d], Vlad Vasilca[c], Yi Xu[c], Fan Zhu[c]

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Thank you for the attention!