ISOSPIN MIXING VIA GDR DECAY: AN OVERVIEW AND RECENT RESULTS

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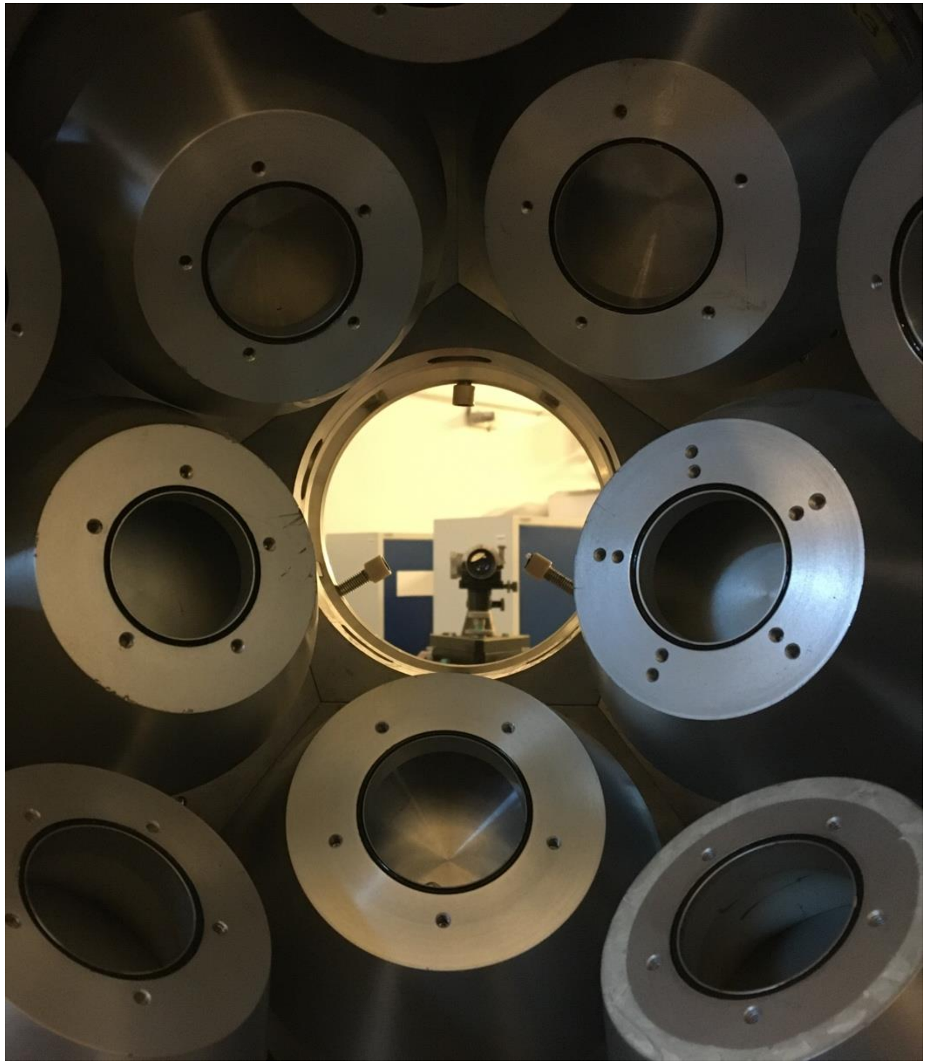
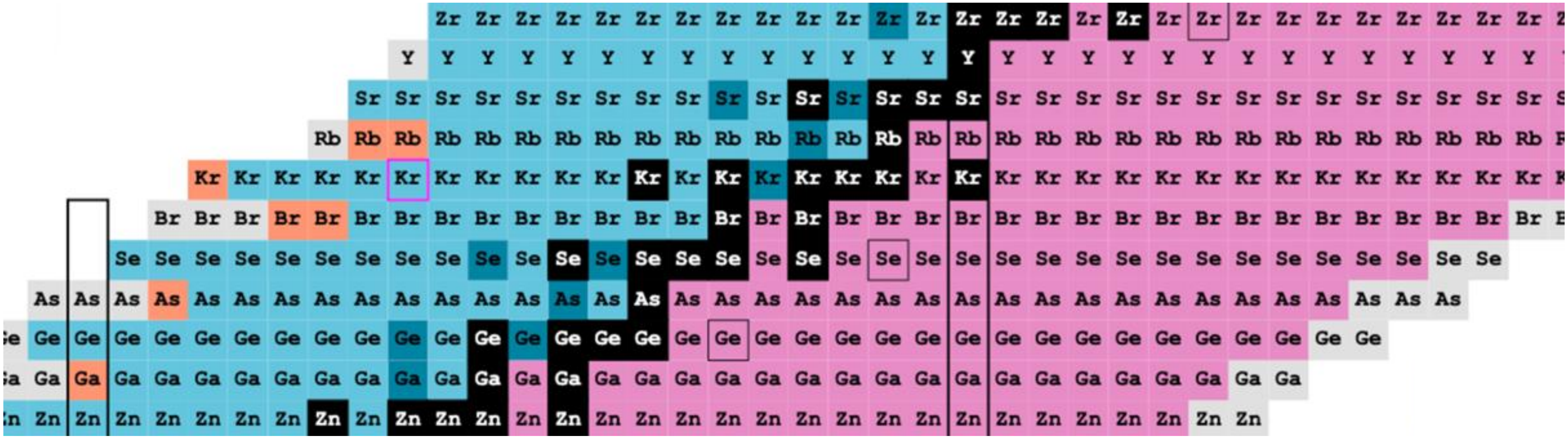
OUTLINE

- Motivations
  - Isospin mixing
  - Isospin mixing via GDR
  - Why ^{72}Kr?
- Experimental Technique & Setup
- 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 MIXING

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:

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

Mixing Probability in the g.s.

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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 isospin-symmetry-breaking corrected $\mathcal{F}t = (1 + \delta_r)(1 + \boxed{\boldsymbol{\delta_c}})$

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Measuring transition strictly forbidden by isospin conservation.

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- Fermi operator is not nuclear structure dependent
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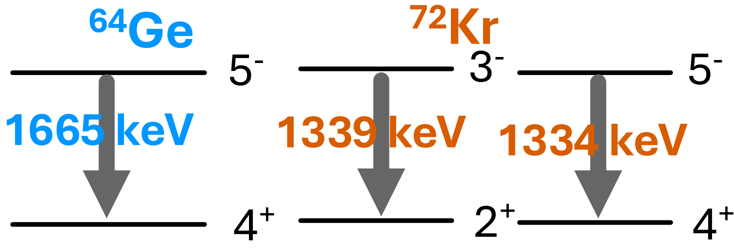

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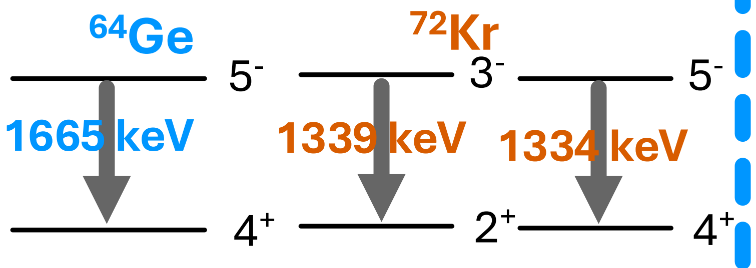

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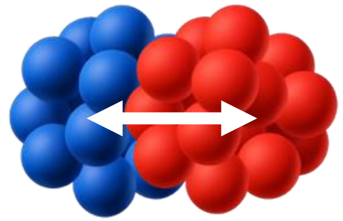

^{72}Kr this work

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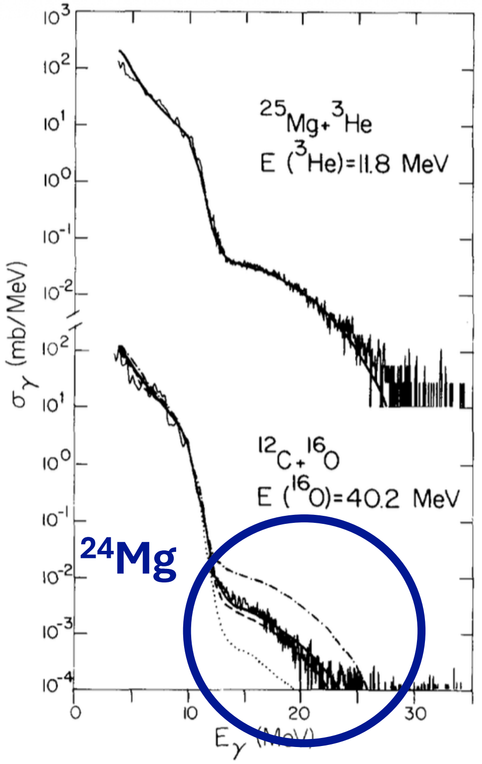
Previous measurements in light nuclei

First investigation of the role of isospin mixing in GDR decay



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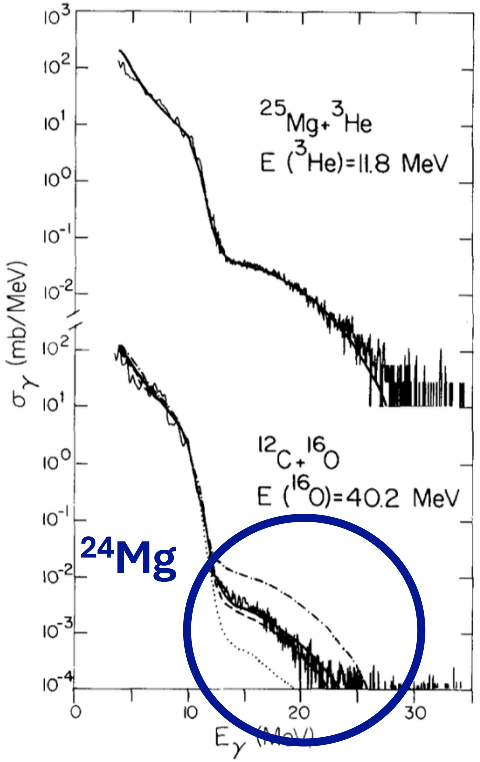

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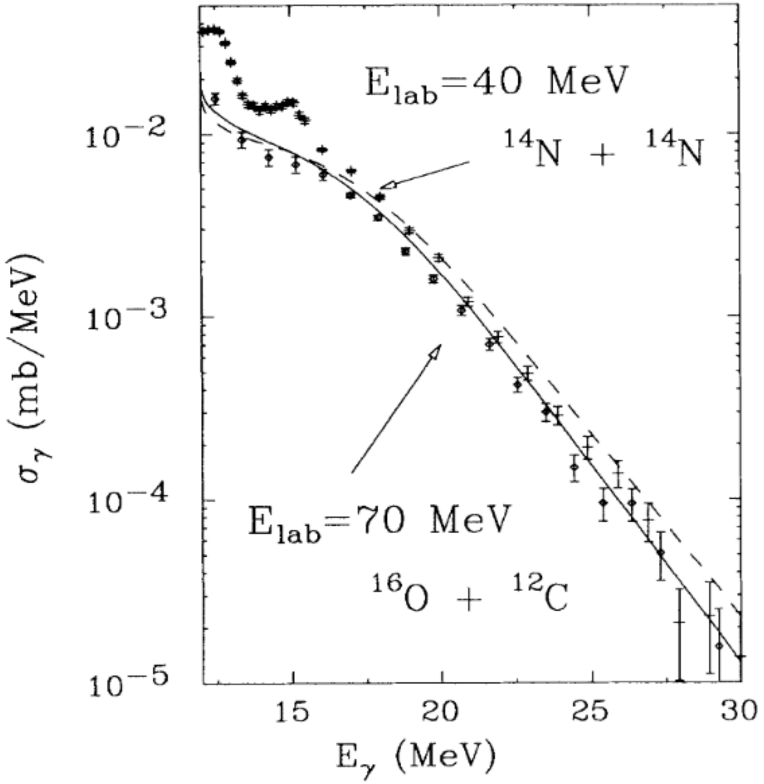
Isospin mixing in ^{28}Si and ^{30}Si



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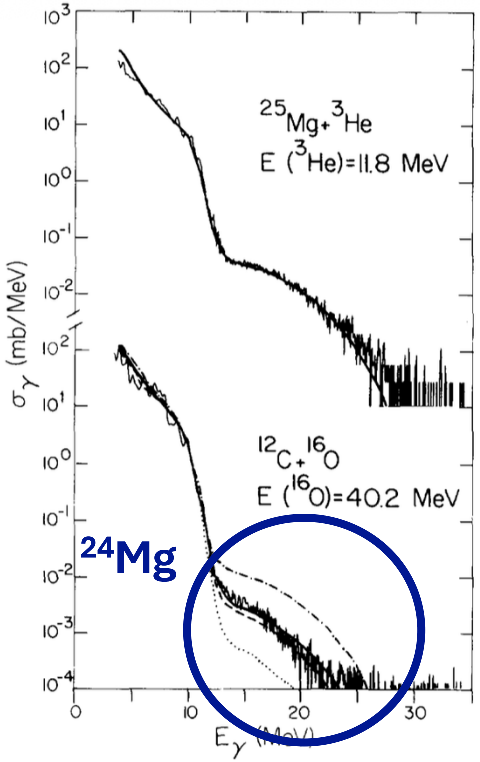

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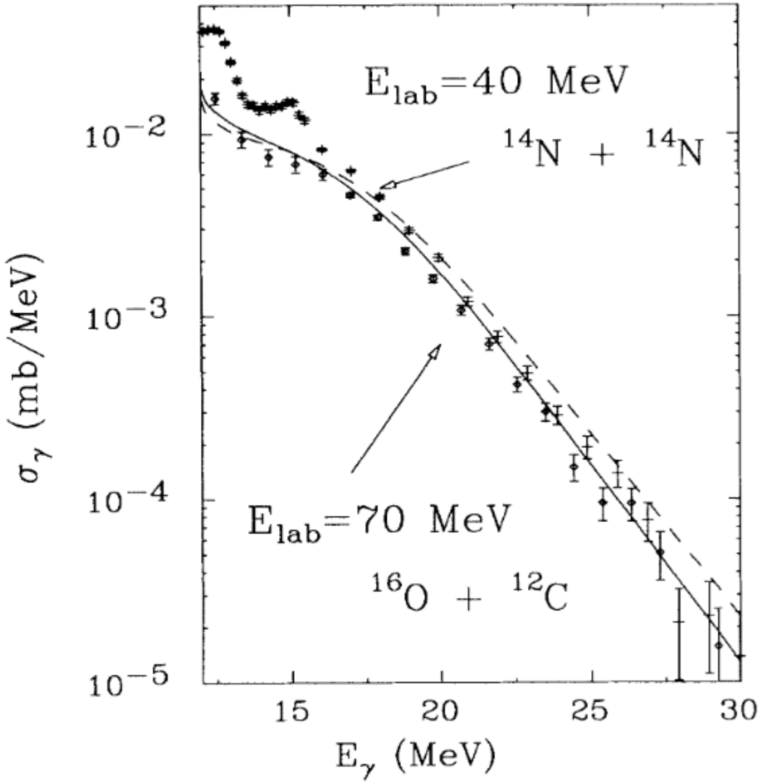

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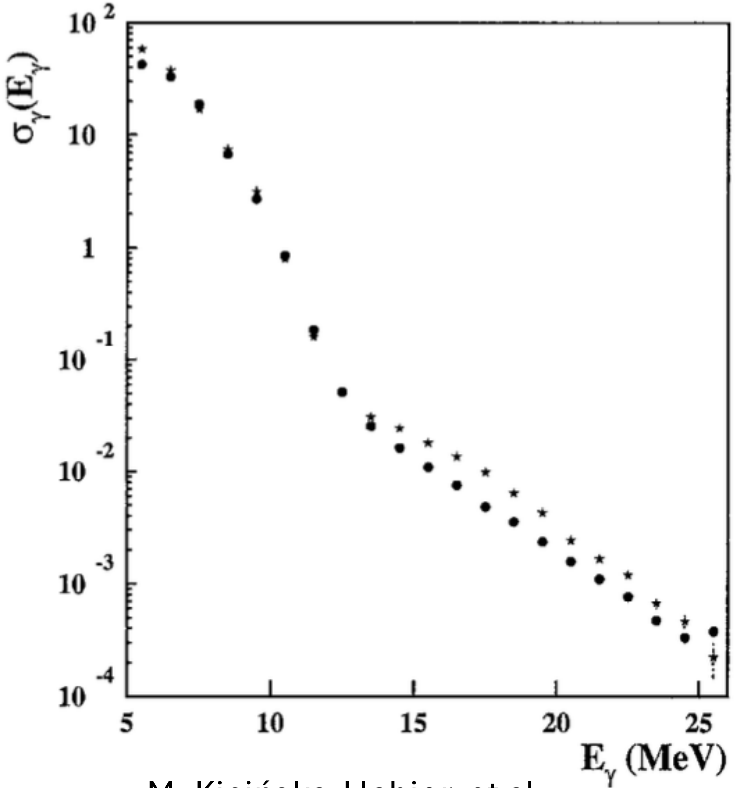

M. Kicińska-Habior, et al.,
Nucl. Phys. A 731 (2004) 138.

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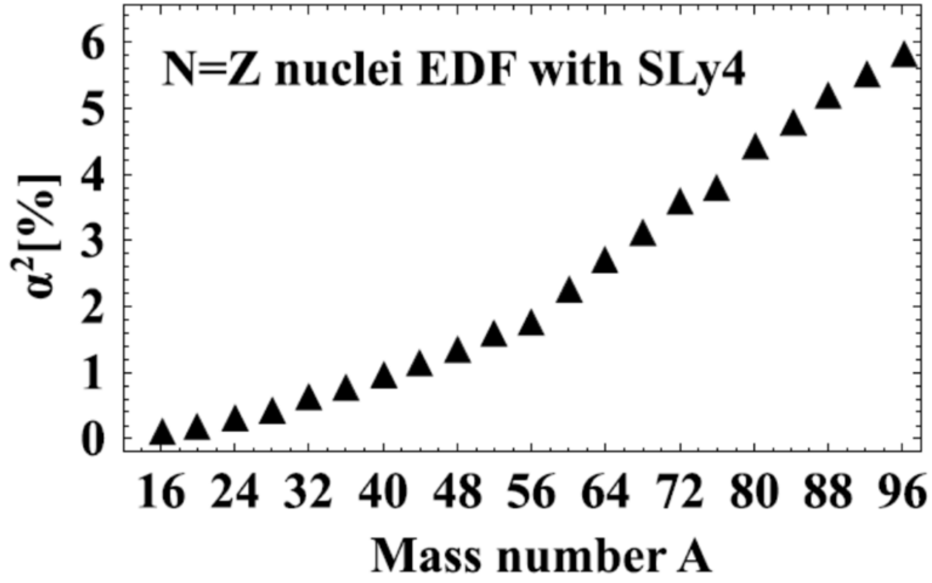

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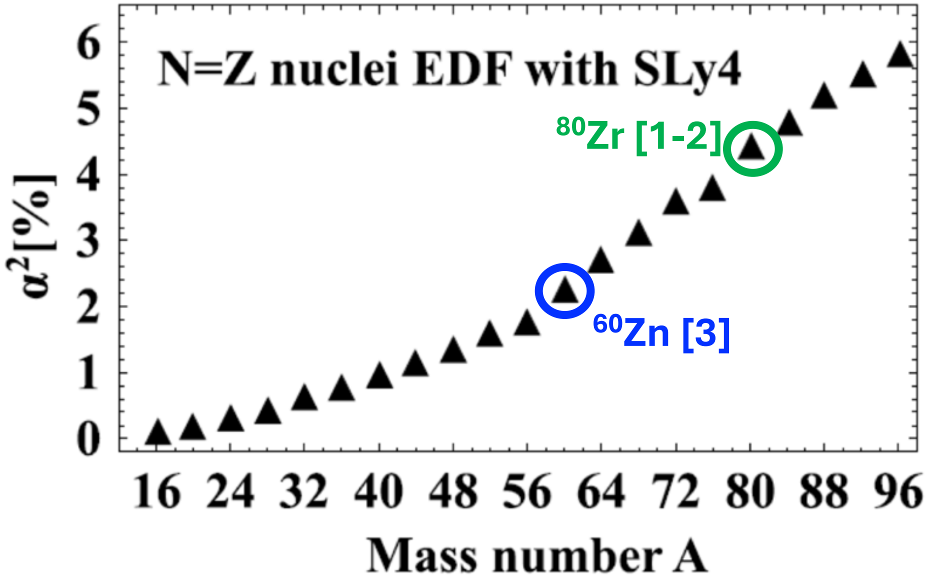

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Nucleus	Temperature	Setup
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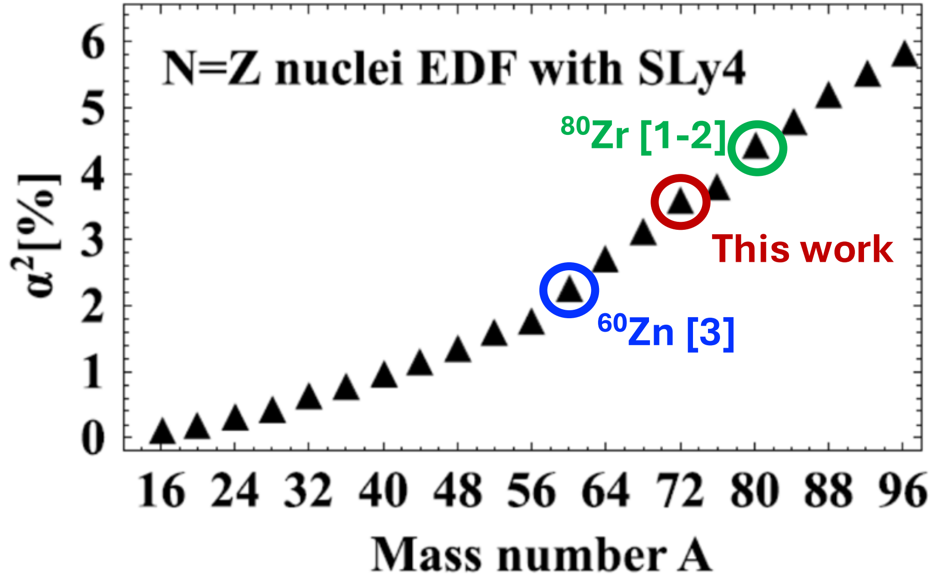

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The new experiment:

Isospin Mixing in ^{72}Kr at the lowest possible temperature at IFIN-HH tandem

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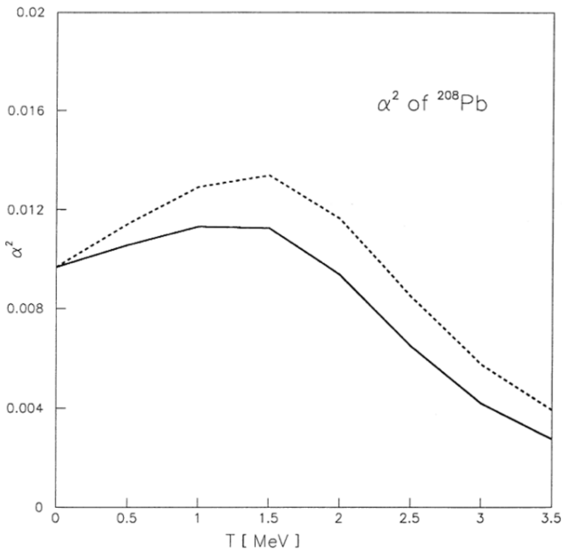

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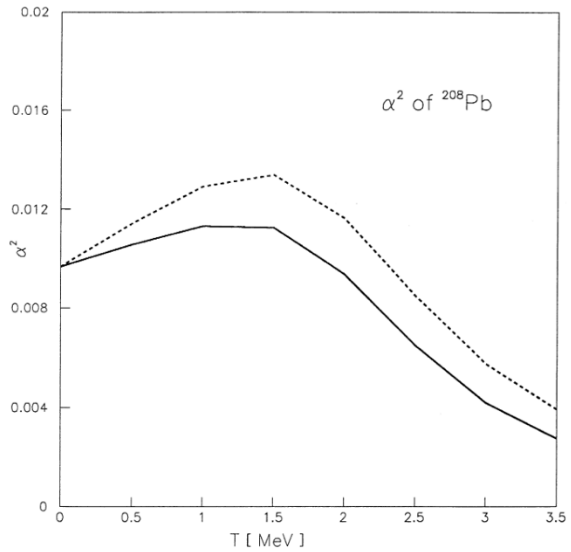

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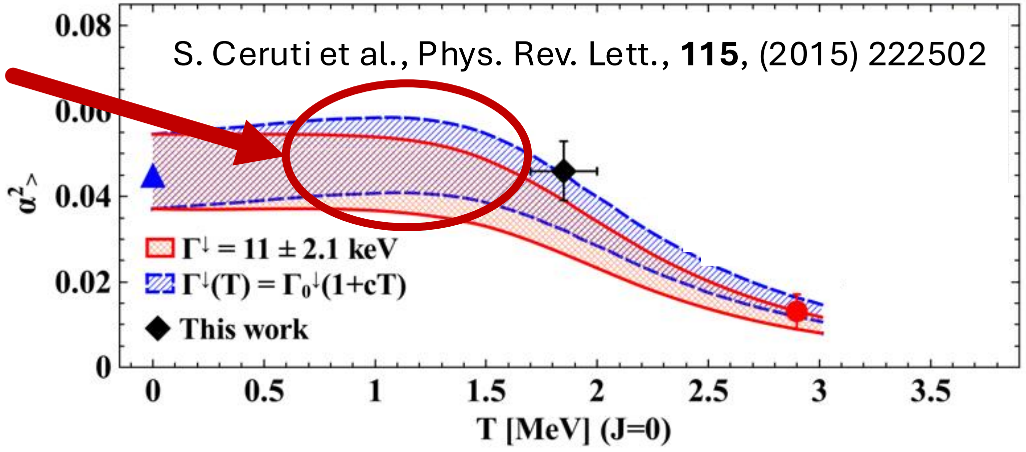

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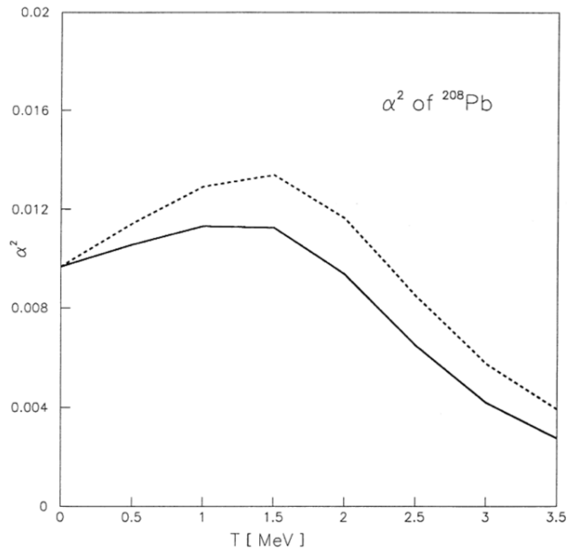

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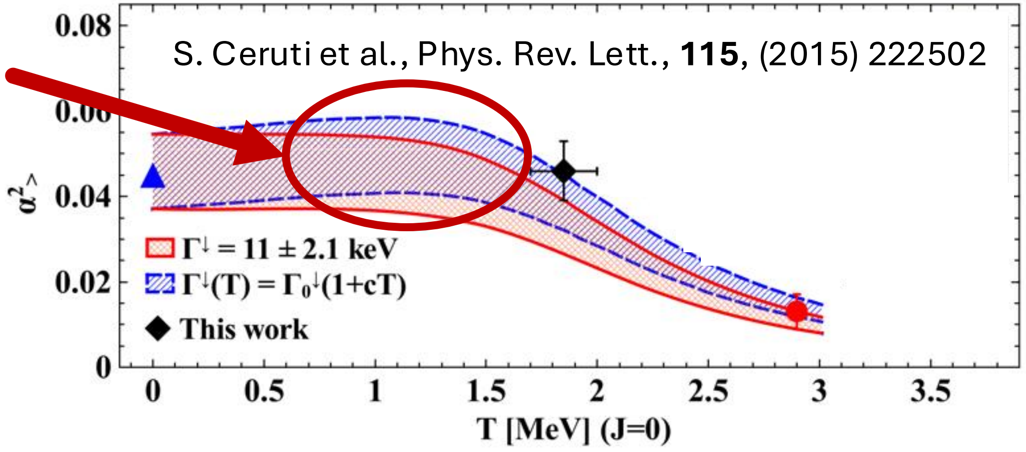

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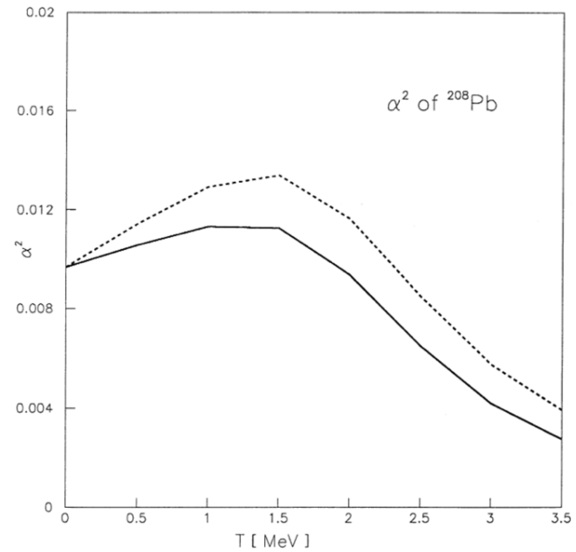

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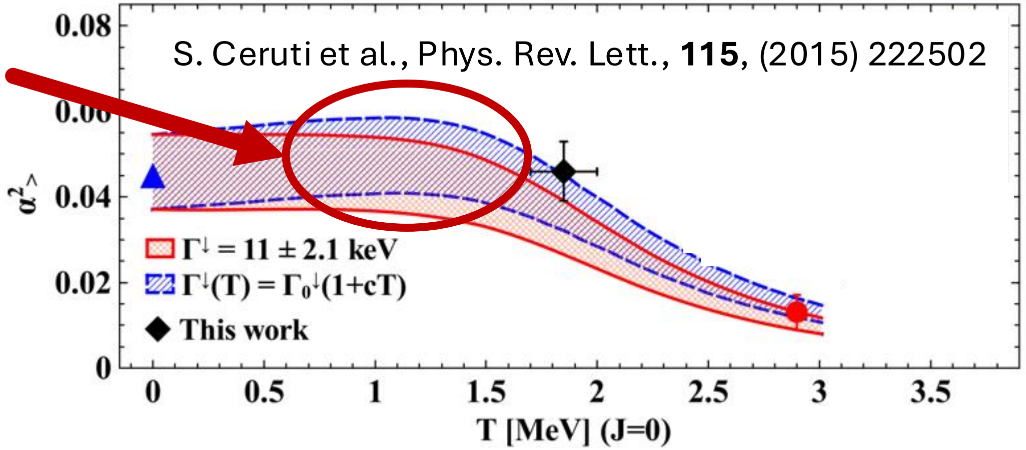

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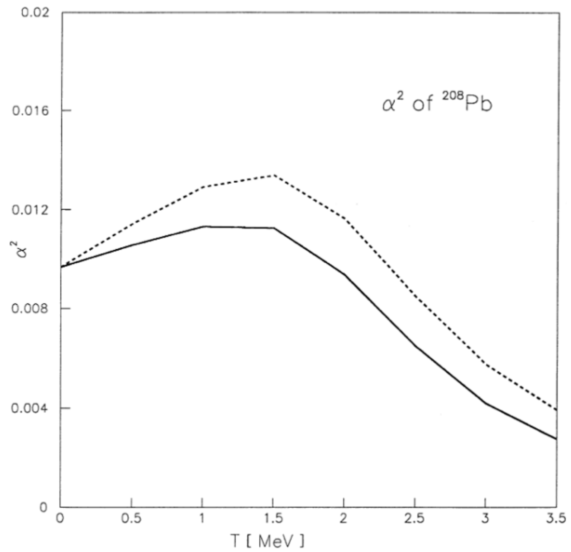

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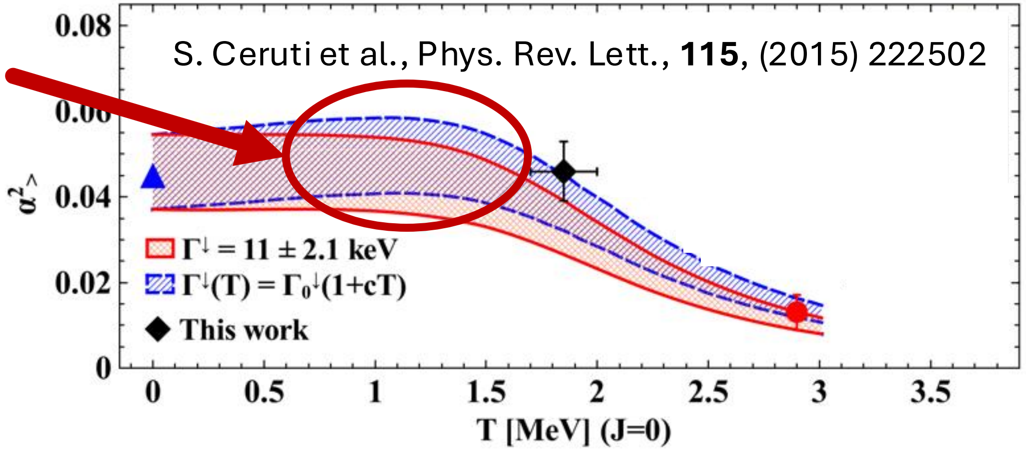

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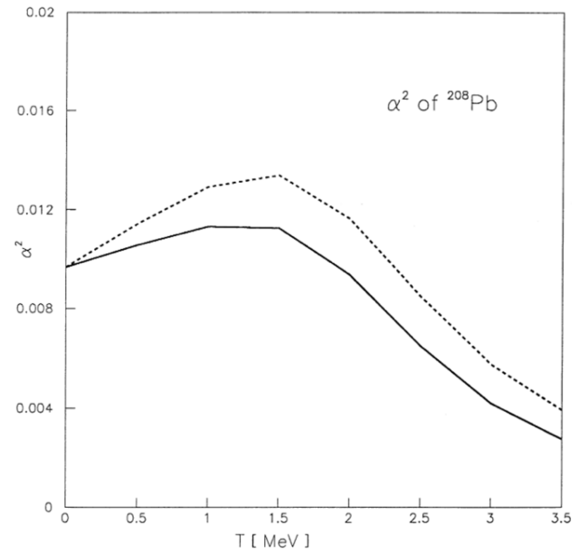

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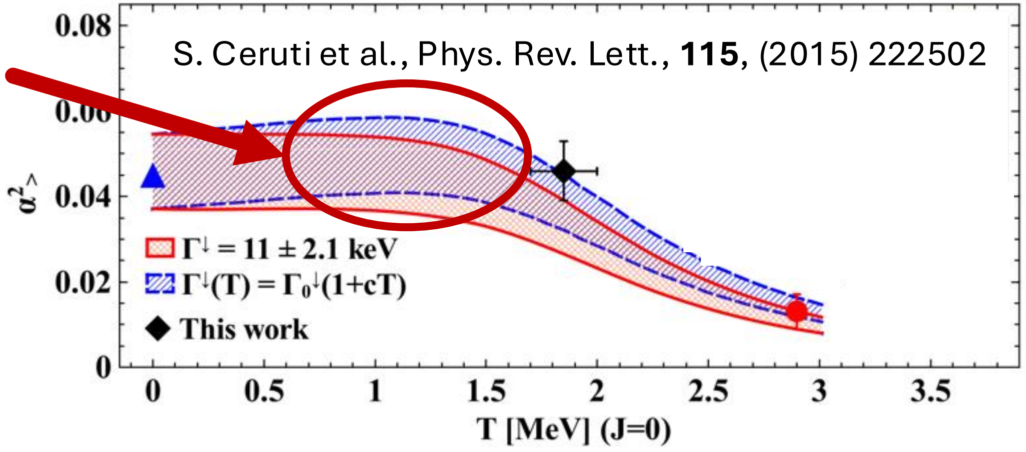

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EXPERIMENTAL TECHNIQUE AND SETUP

ISOSPIN MIXING VIA GDR

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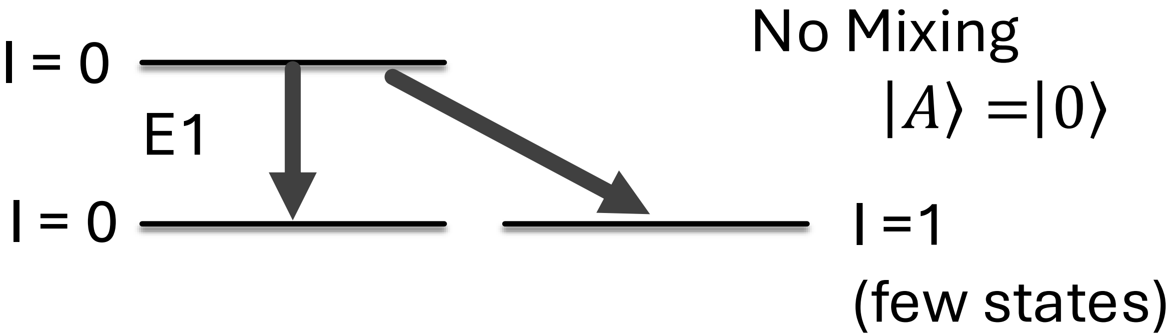

No Mixing

$|A\rangle = |0\rangle$

I = 0

E1

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I =1

(few states)

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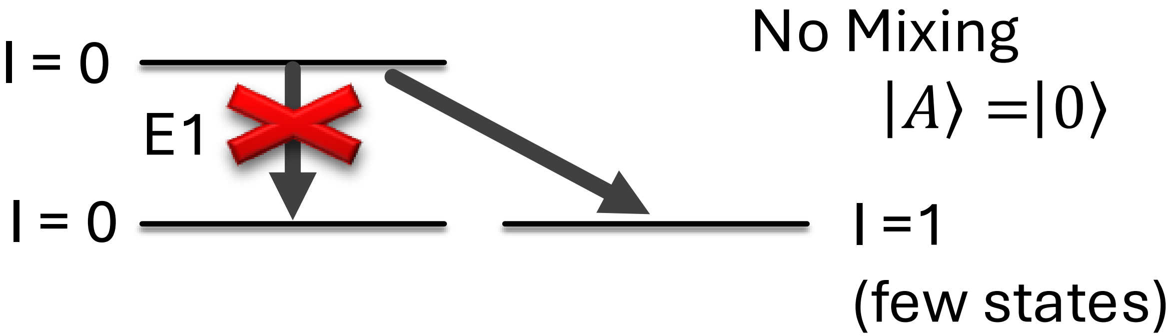

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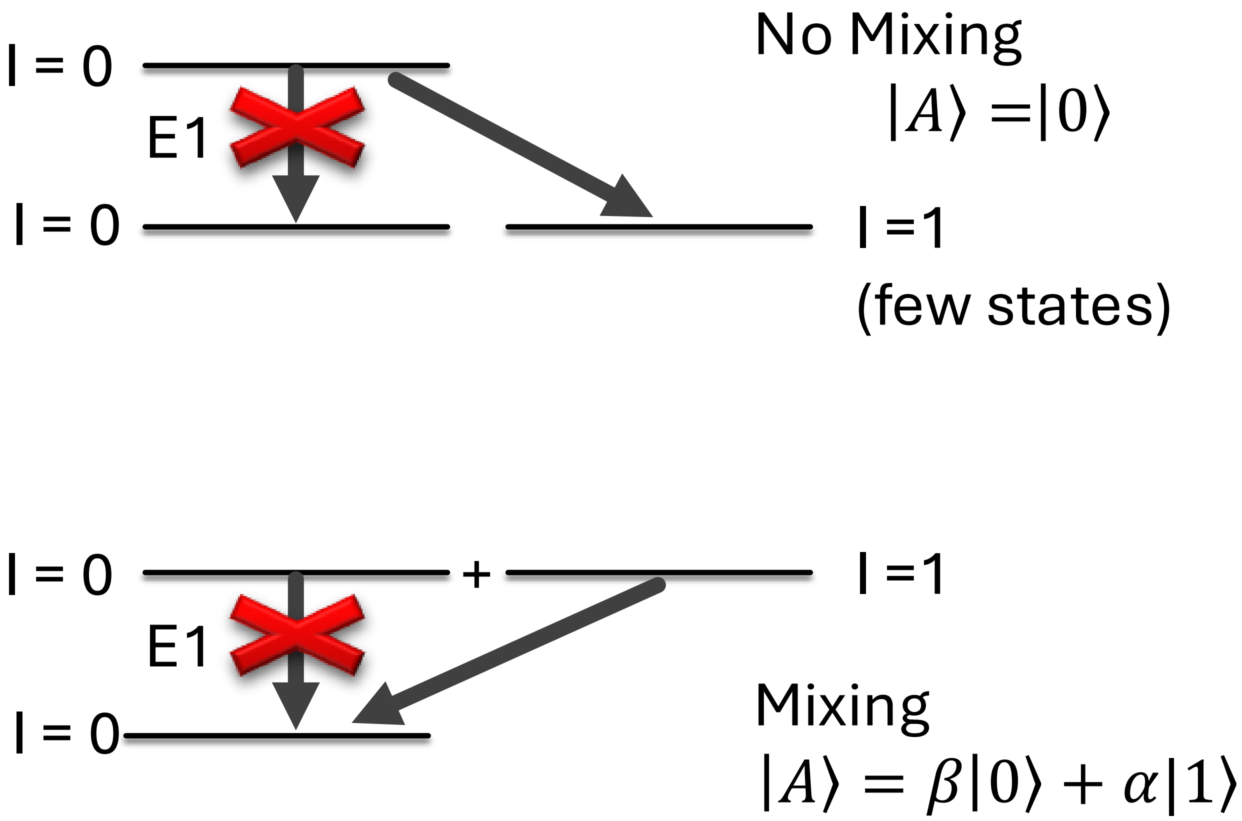

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E1

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I =1

(few states)

I = 0

+

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E1

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Mixing

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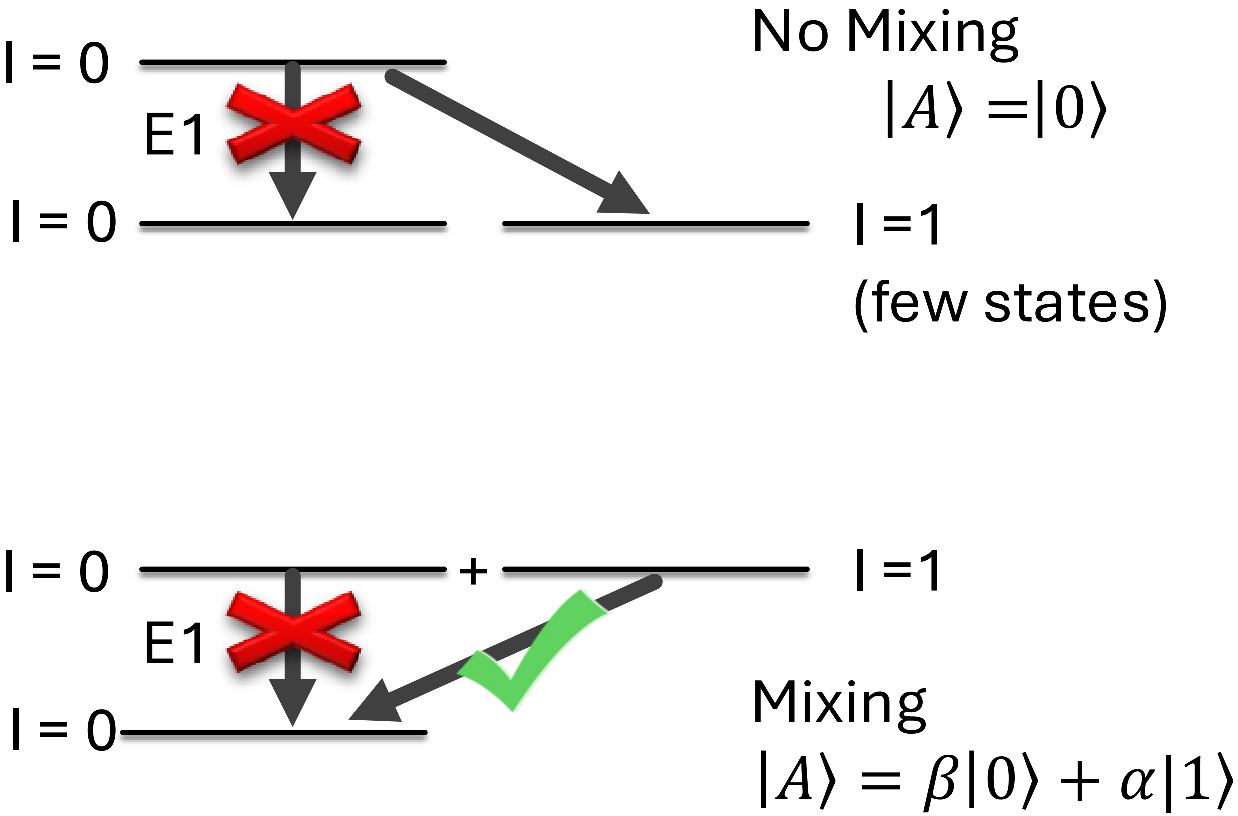

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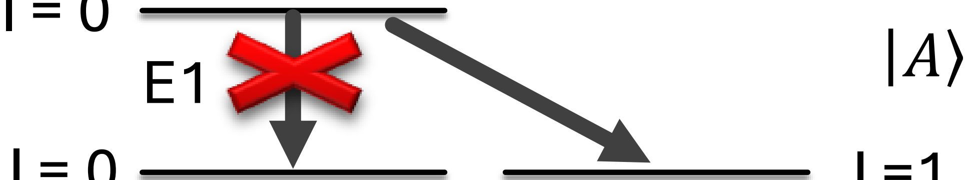

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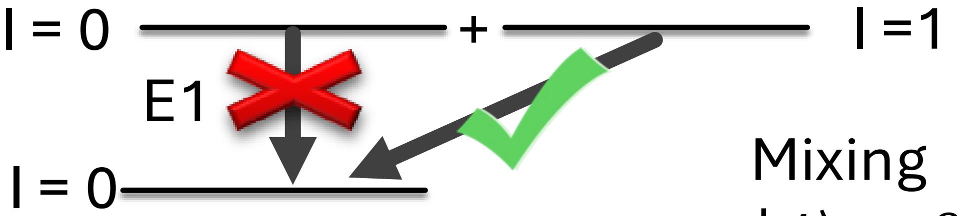

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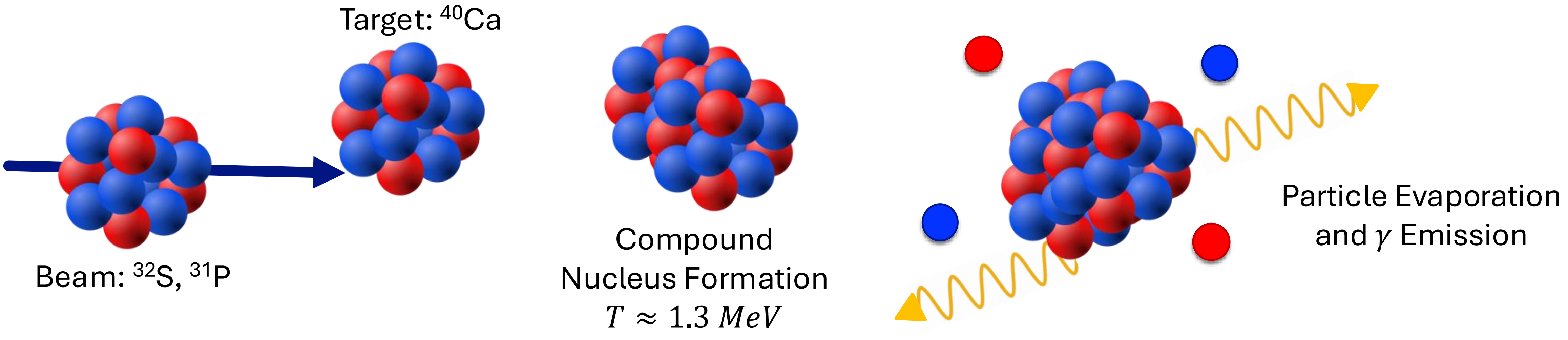

Target: ^{40}Ca

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

Compound Nucleus Formation
$T \approx 1.3\ MeV$

Particle Evaporation and γ Emission

$I = 0$ compound nucleus reaction:

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

The observed E1 strenght is a signature of the mixing.

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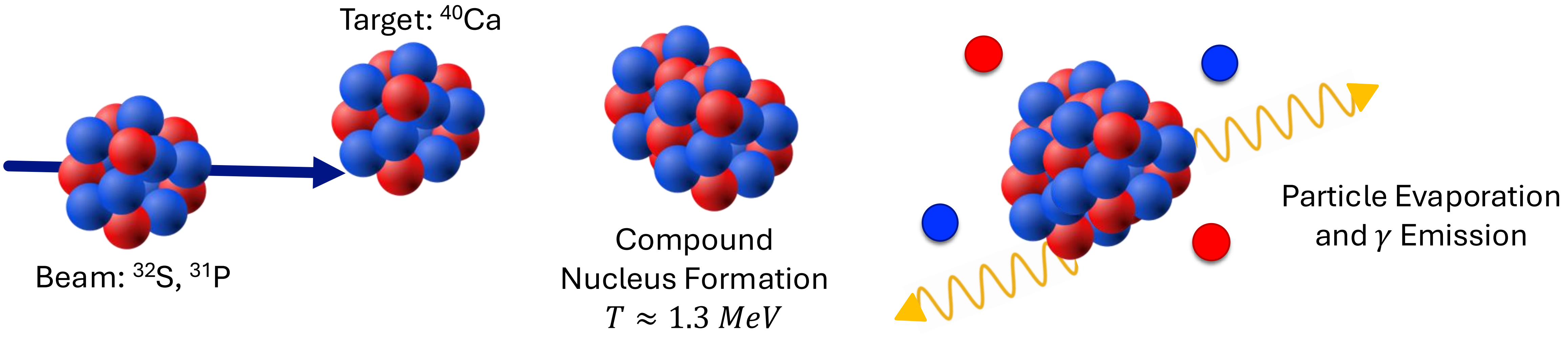
$$^{31}P + {}^{40}Ca \rightarrow {}^{71}Br^{*}$$

Full mixing. No E1 strength reduction is expected.

EXPERIMENTAL TECHNIQUE: GDR (II)



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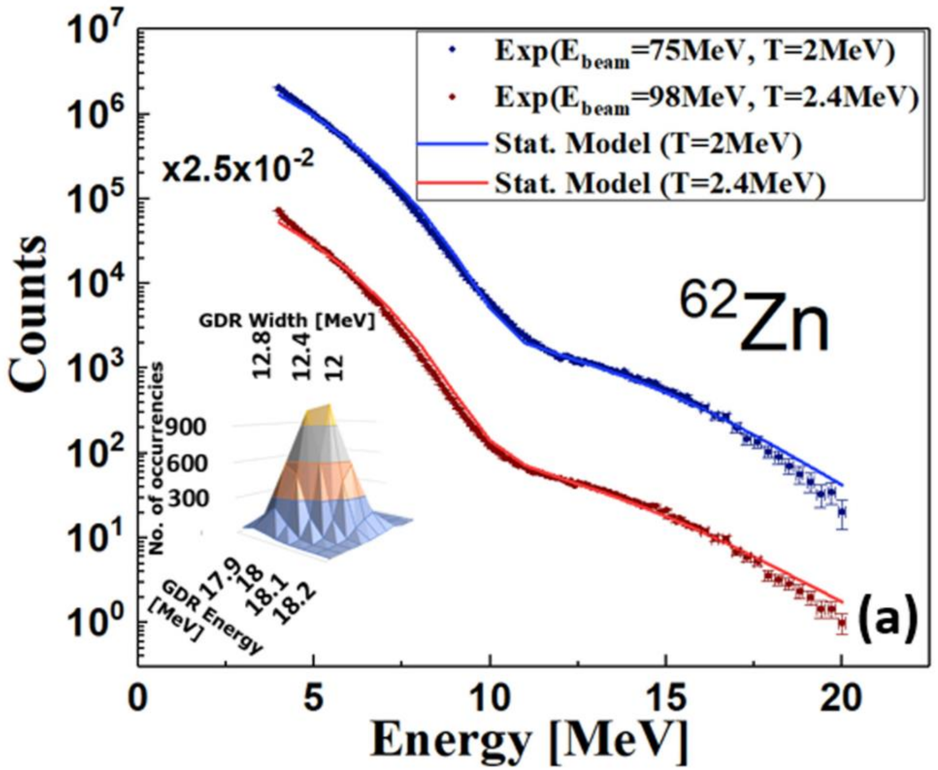
GDR manifest itself as E1 Strenght → GDR is a probe of the isospin mixing

DATA ANALYSIS TECNIQUE

Reaction with I ≠ 0, no GDR decay suppression



G. Gosta et al., PRC 103, L041302 (2021)

Statistical model to extract of GDR parameters:

centroid, width and strenght

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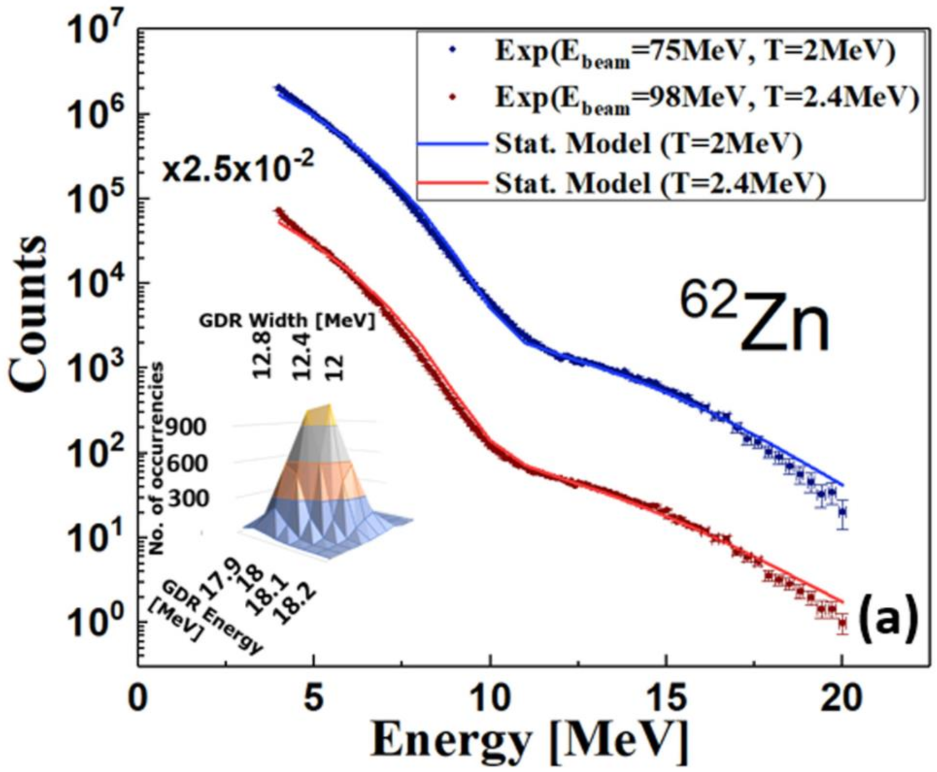

G. Gosta et al., PRC 103, L041302 (2021)

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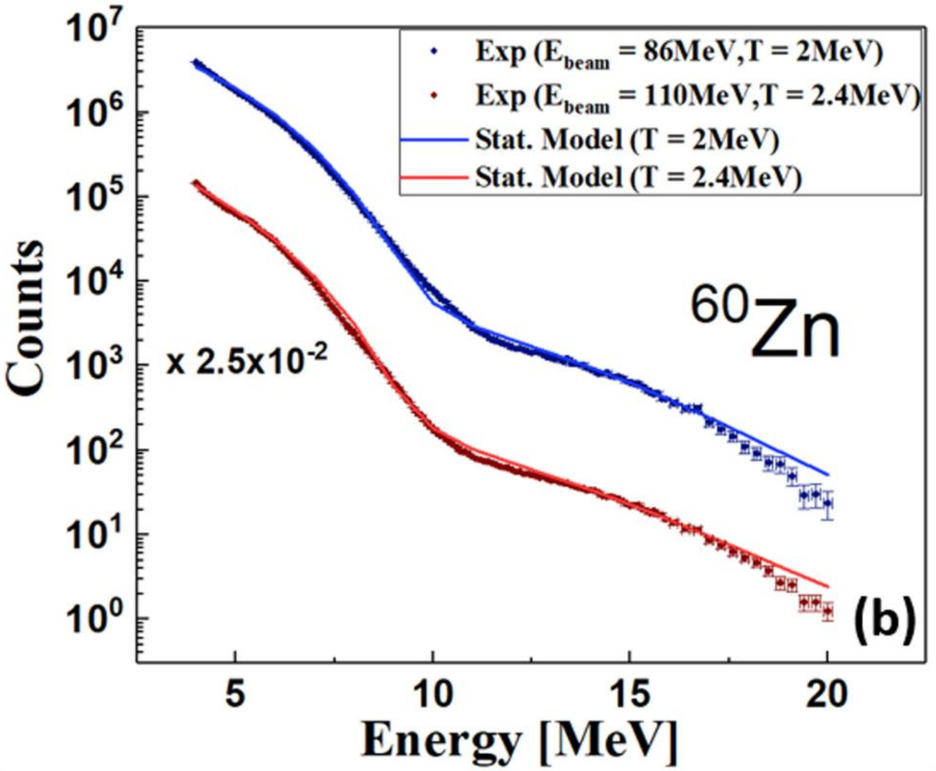
Reaction with I = 0, GDR decay possible only in case of isospin mixing



G. Gosta et al., PRC 103, L041302 (2021)

Statistical model to extract the

Coulomb Spreading Width $\Gamma_c^{\downarrow}$

EXPERIMENTAL SETUP

${}^{32}S + {}^{40}Ca \rightarrow {}^{72}Kr^{*}$ @ 90 MeV

${}^{31}P + {}^{40}Ca \rightarrow {}^{71}Br^{*}$ @ 82 MeV

Low cross-section

⇩

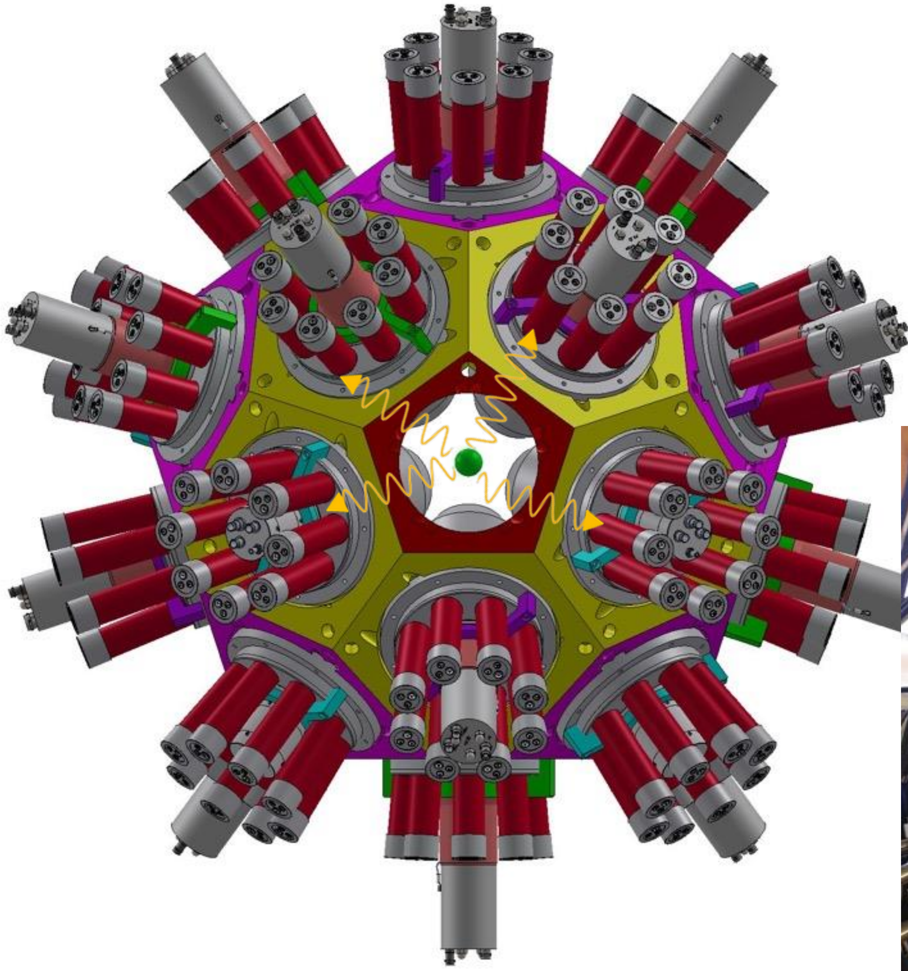
High efficiency

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)



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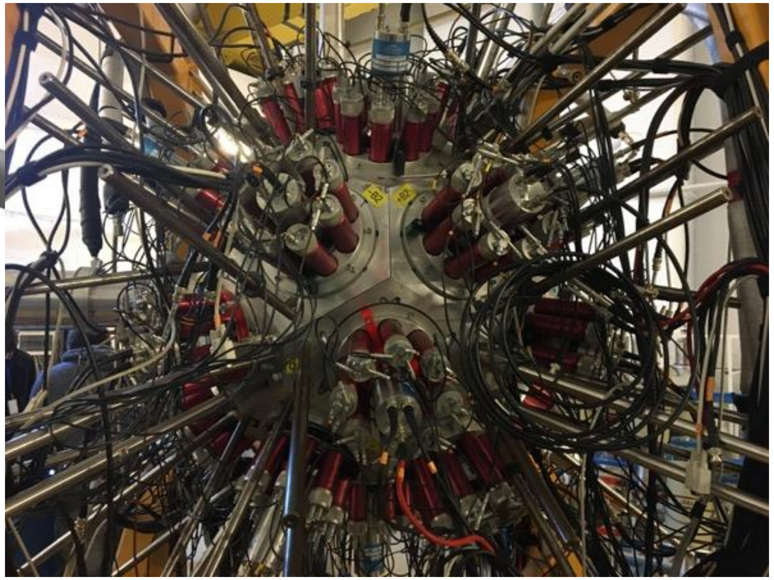

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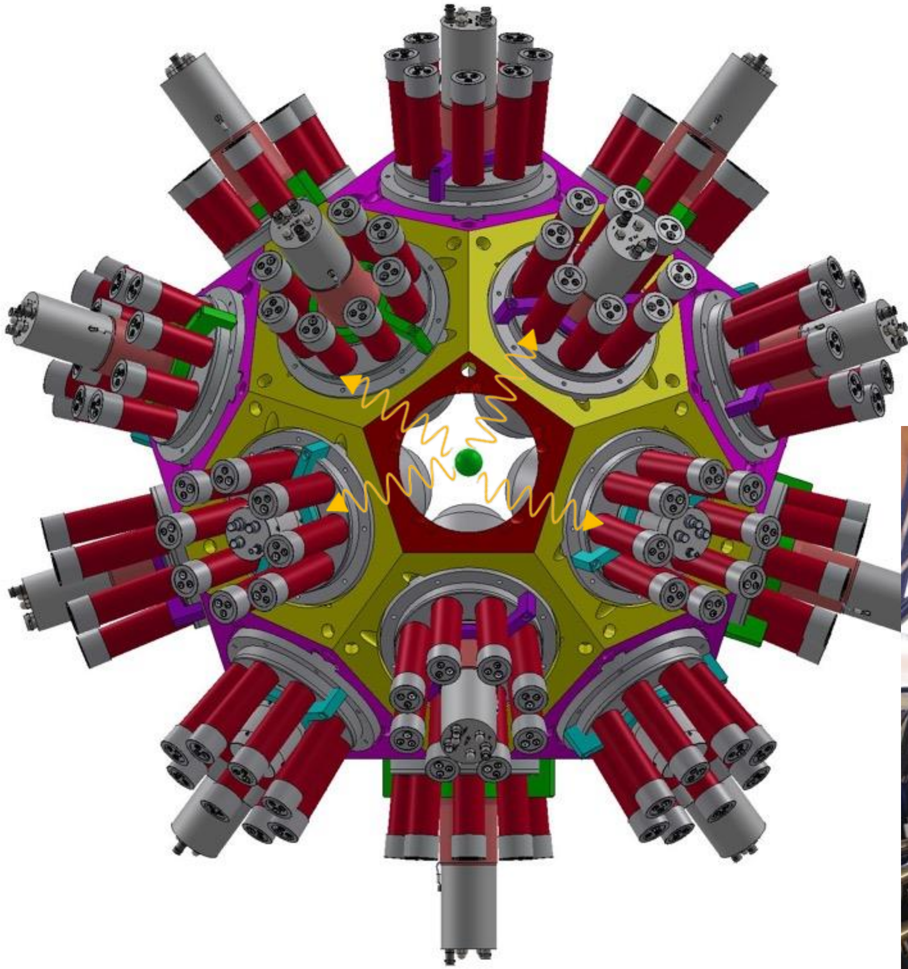

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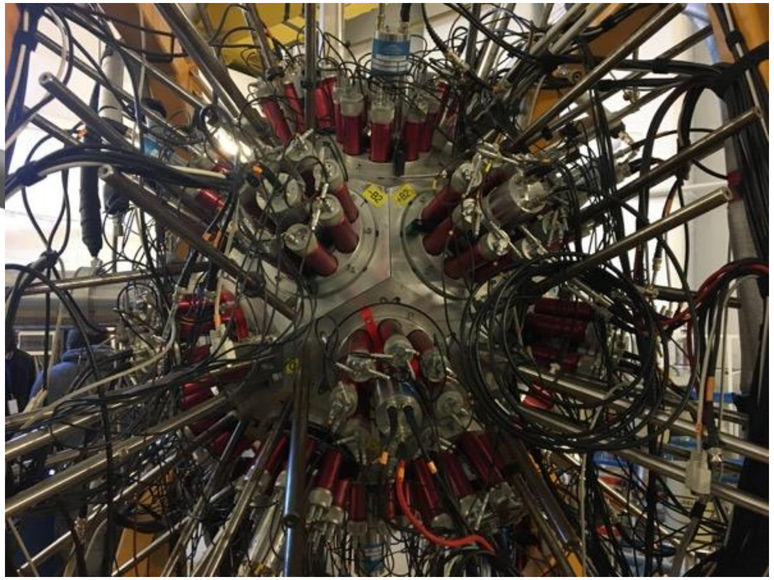
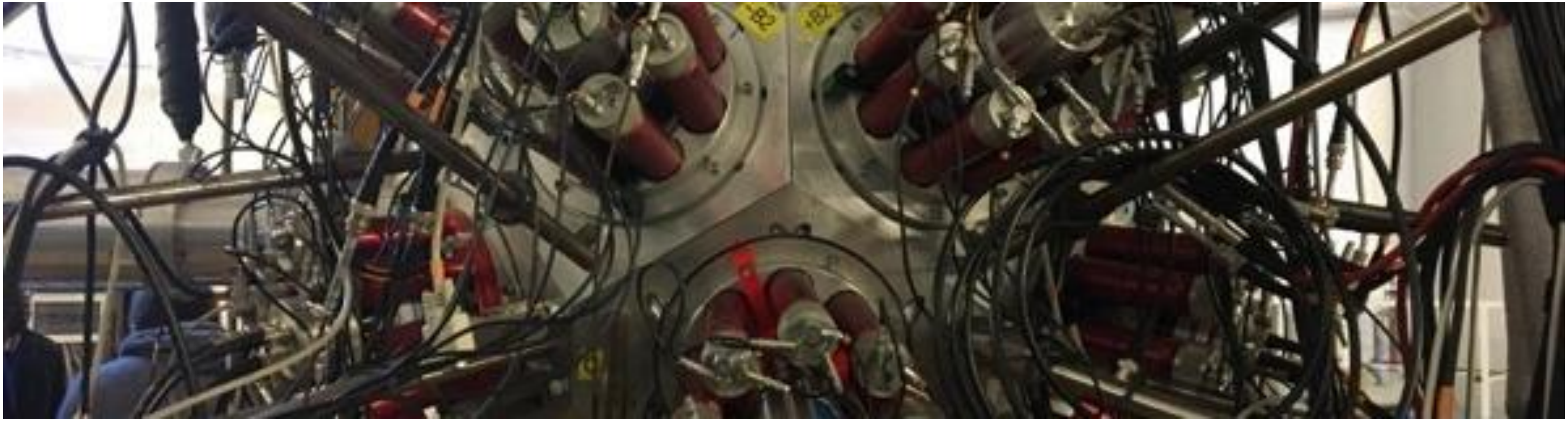




RESULTS

ISOSPIN MIXING PARAMETRES: α^2 & δ_c

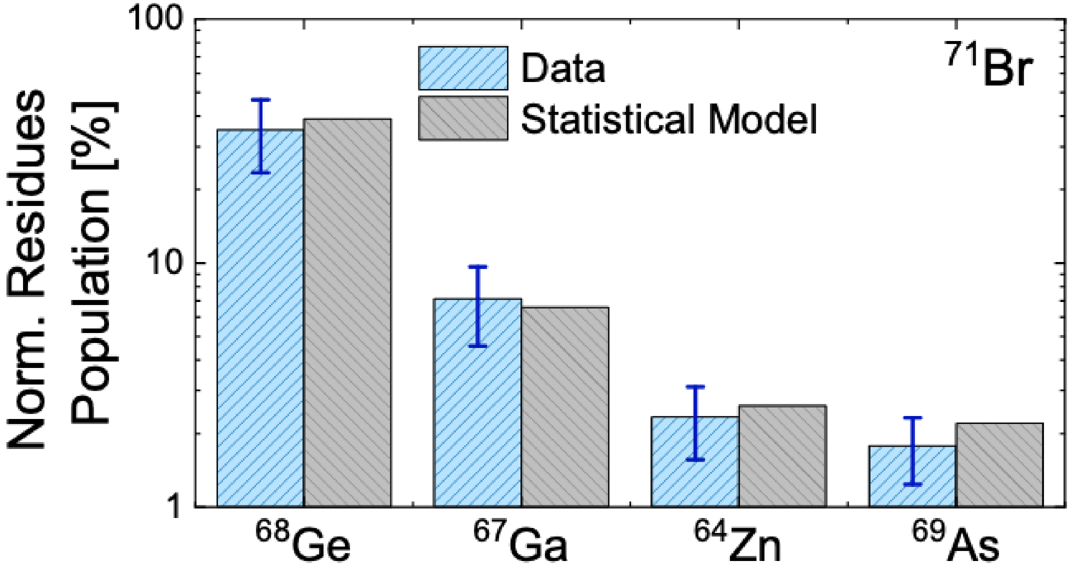
RESULTS: EVAPORATION RESIDUES

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

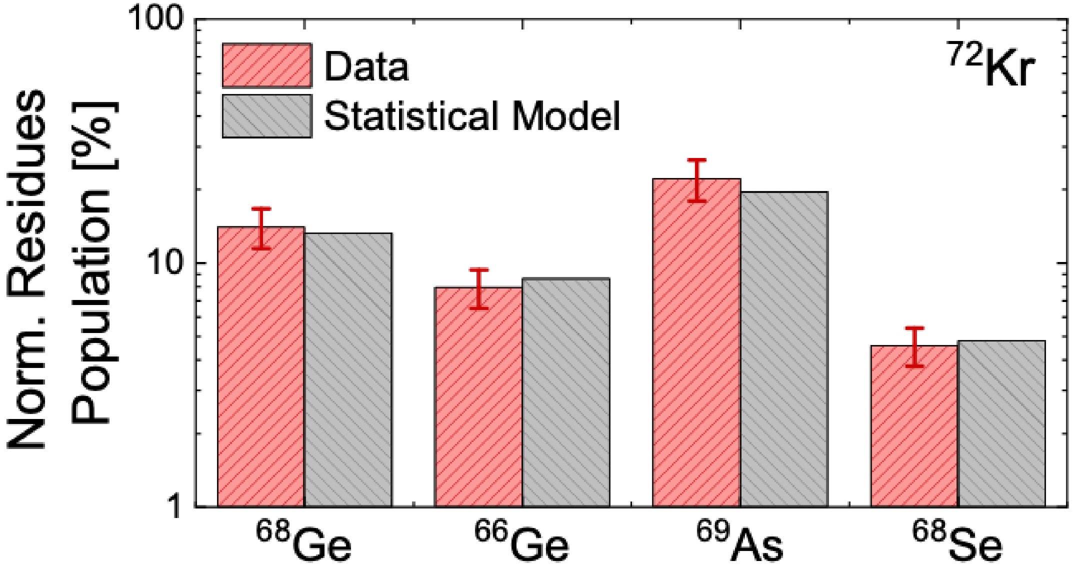
Experimental population of the residues compared with the statistical model prediction.

The most populated residues are reproduced within the error bars.

Reaction with $I \neq 0$



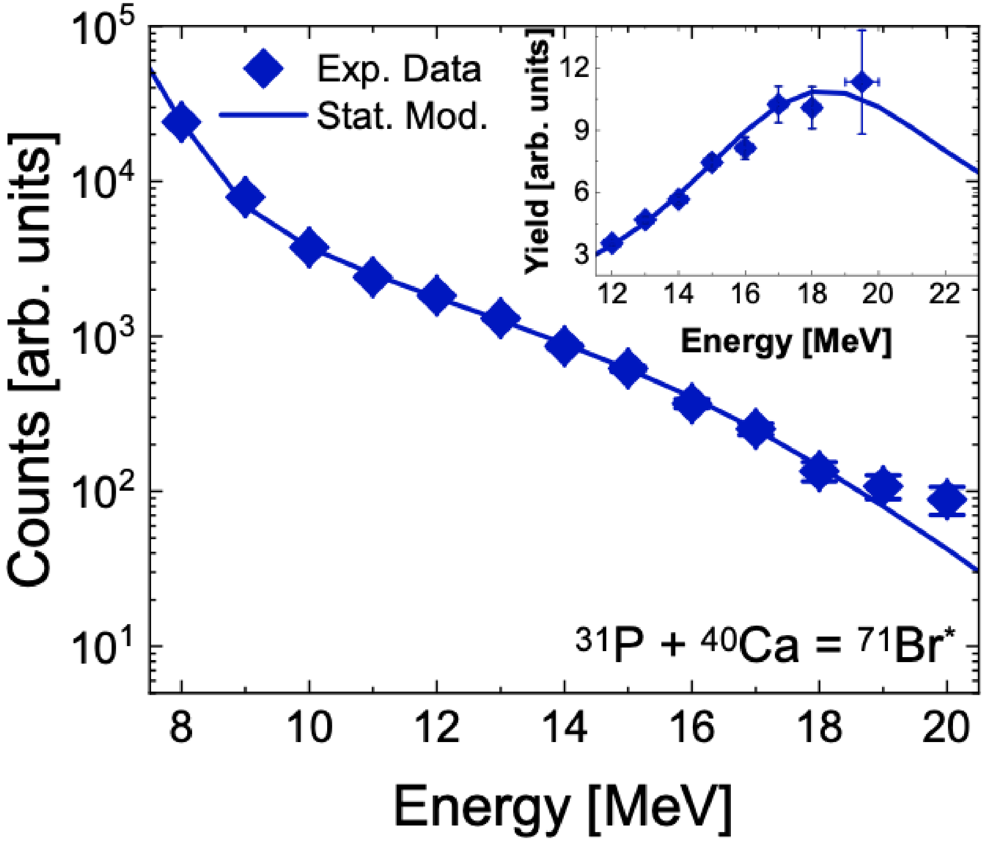
Reaction with $I = 0$



A. Giaz et al., Phys. Lett. B, **868** (2025) 13965

RESULTS: HIGH-ENRGY γ-RAY SPECTRA

$$I \neq 0 - E_{GDR} = 18.4 \pm 0.5\ MeV\ \&$$
$$\Gamma_{GDR} = 11 \pm 1\ MeV$$



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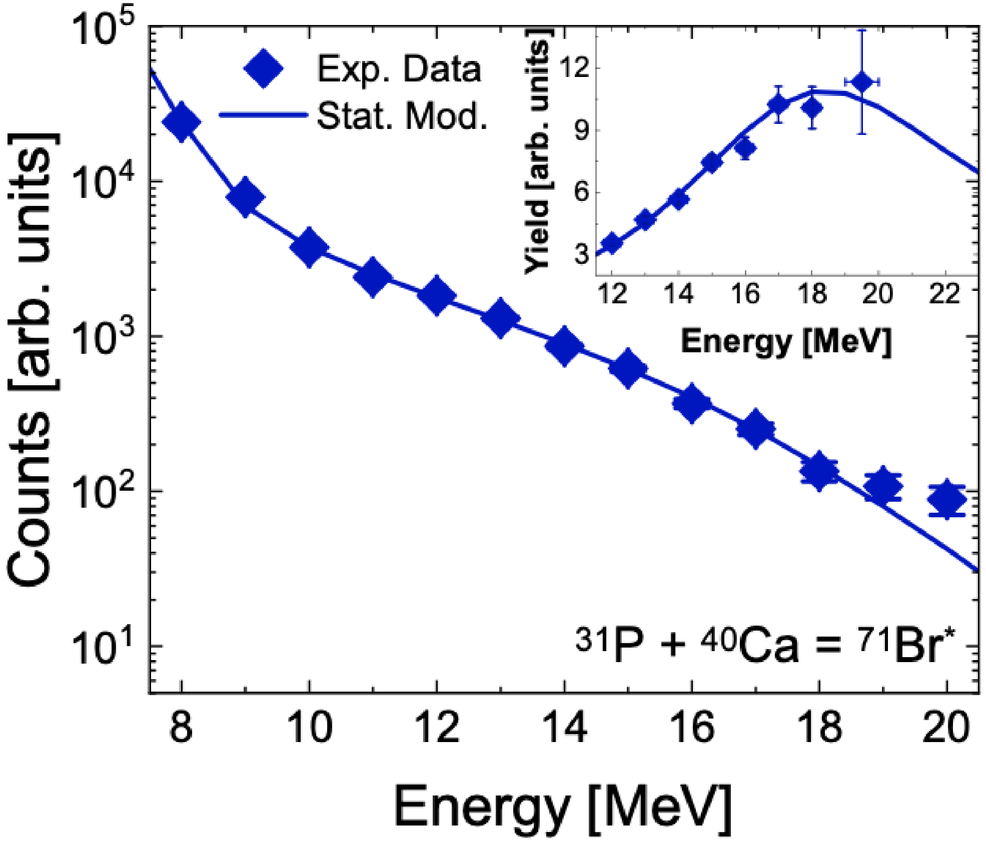

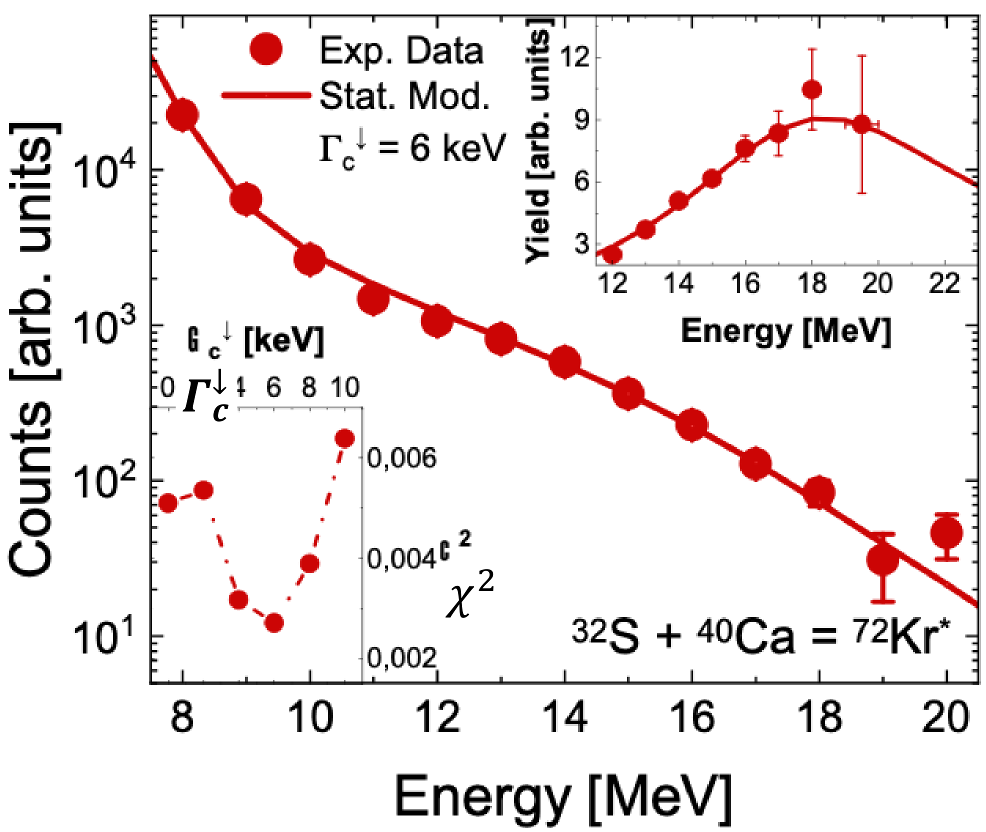

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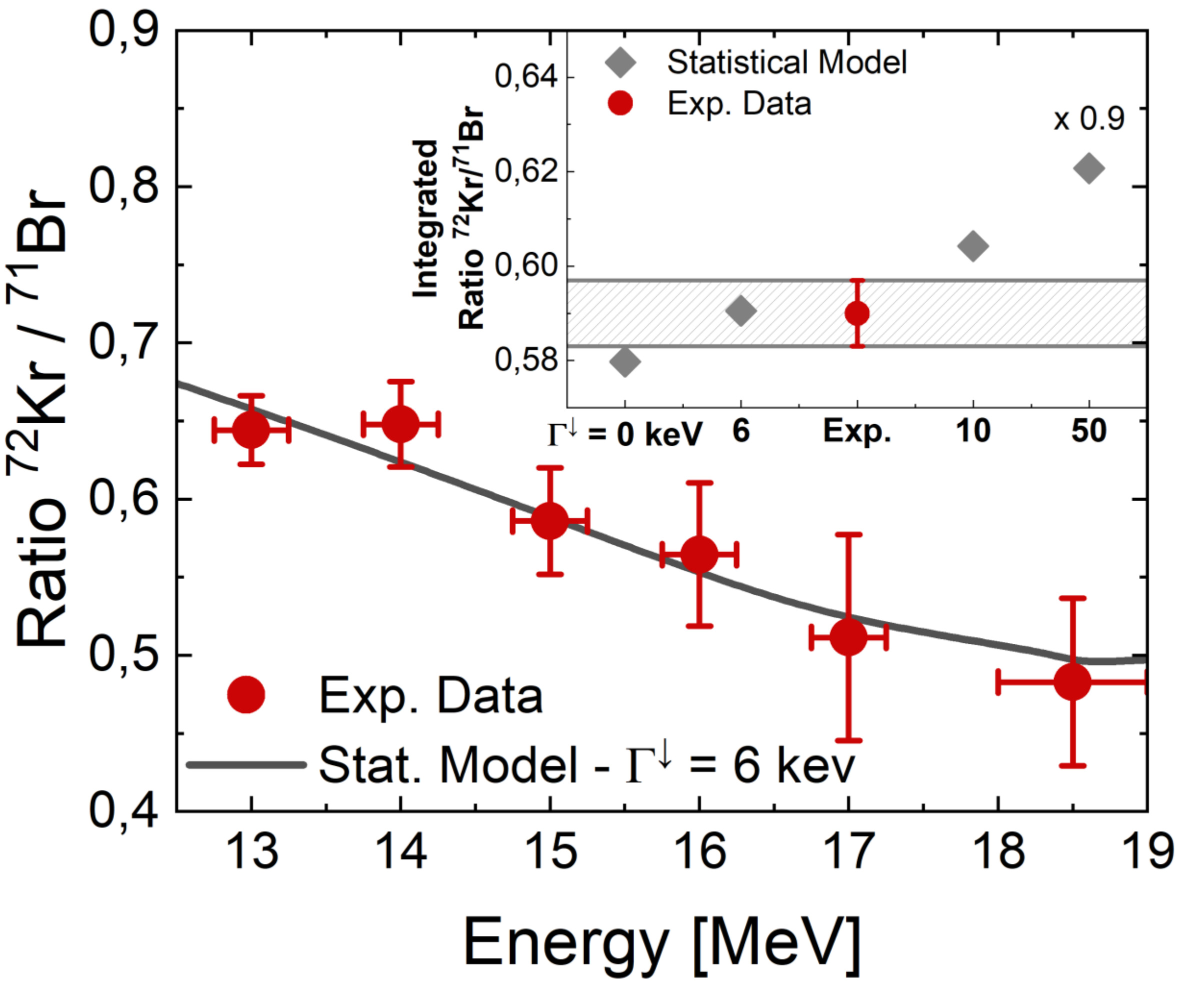
Statistical model with different values of $\Gamma_c^{\downarrow}$: 0 (no mixing), 6, 10 and 50 keV (full mixing).



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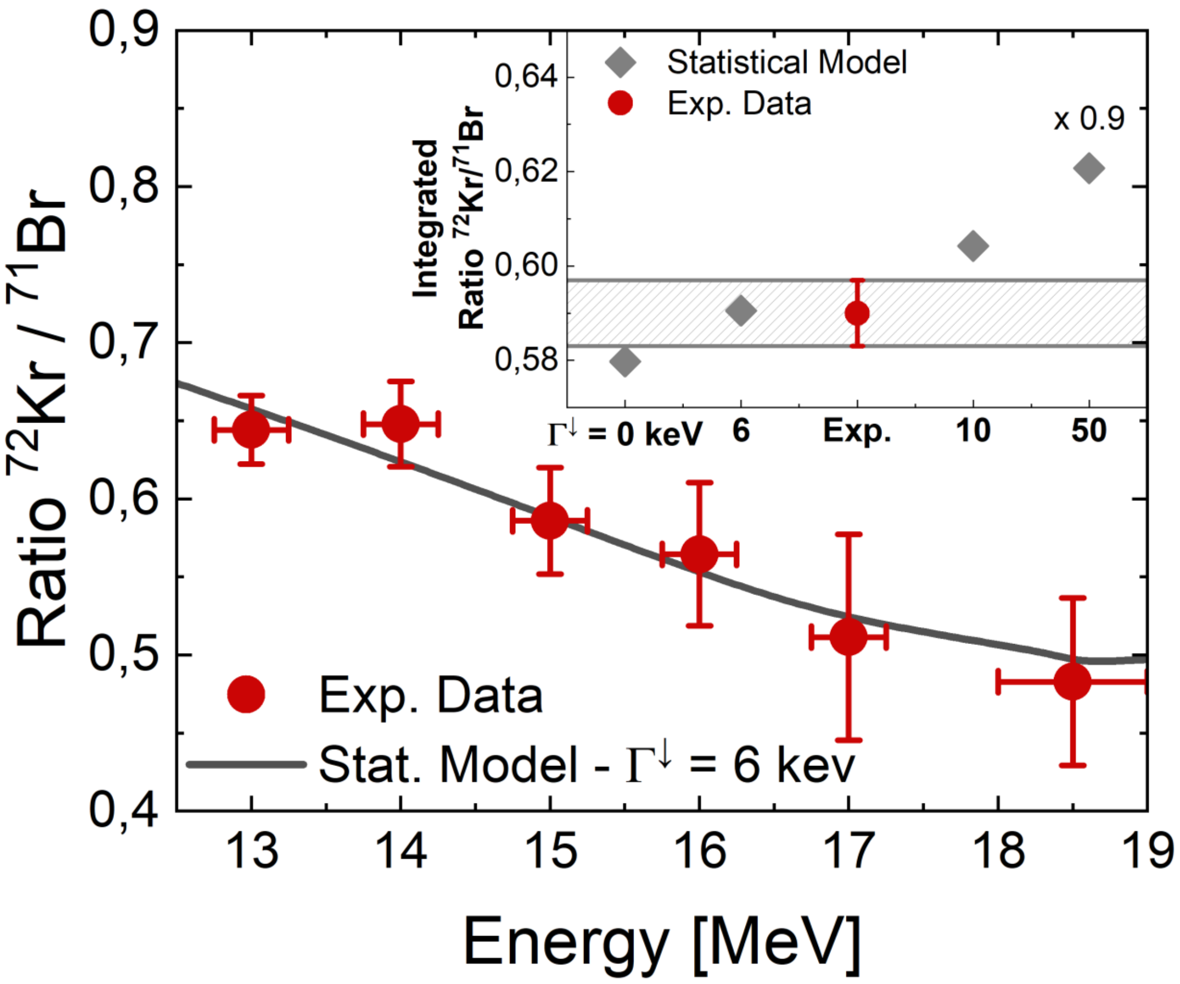
Integrated Ratio ^{72}Kr and ^{71}Br from 13 MeV to 18 MeV:

- Experimental data:

$$\mathbf{0.590 \pm 0.007}$$



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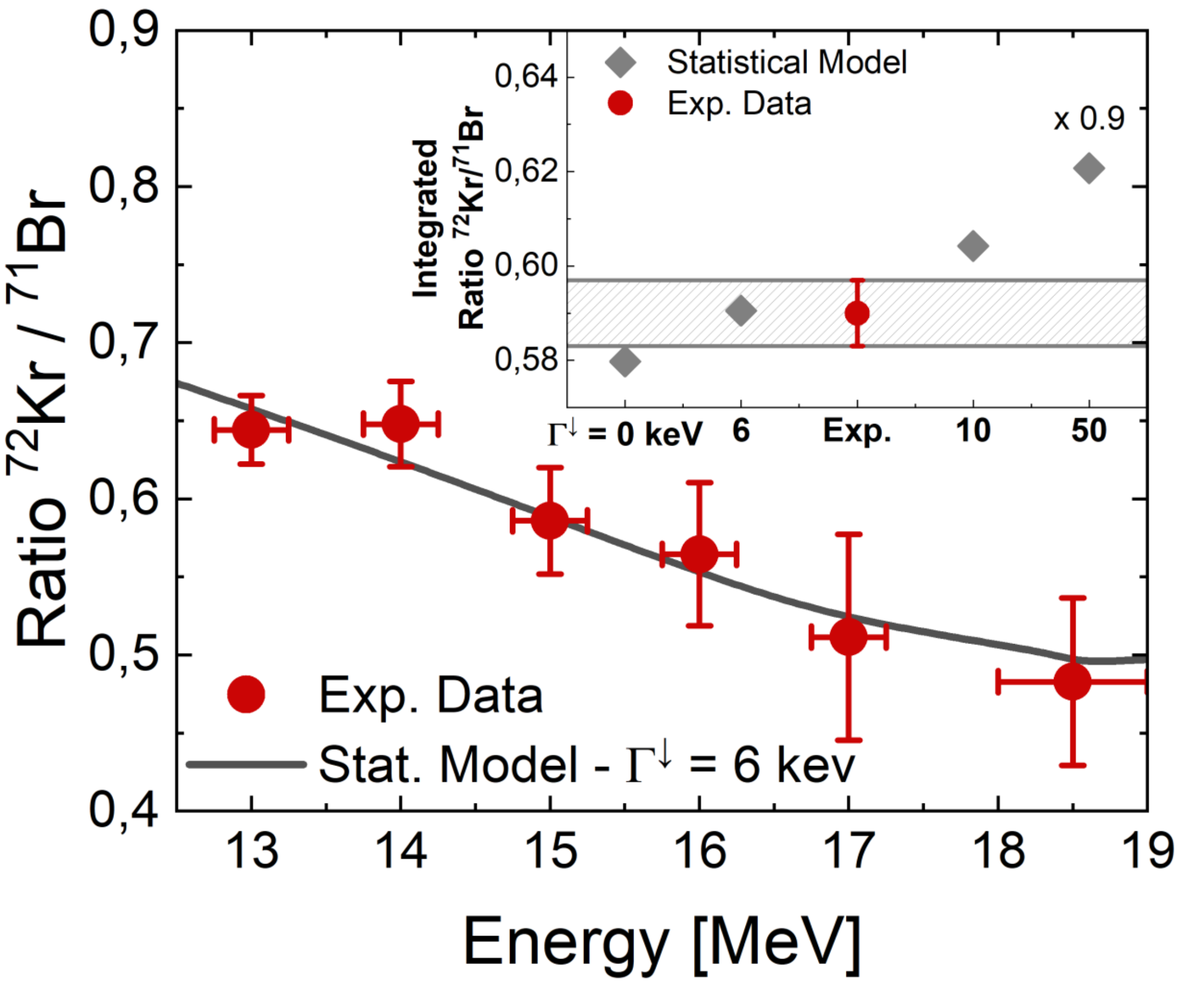

A. Giaz et al., Phys. Lett. B, **868** (2025) 13965

RESULTS: α^2 MIXING PARAMETER (I)

From T>0 to T=0

α^2 trend as a function of temperature:

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

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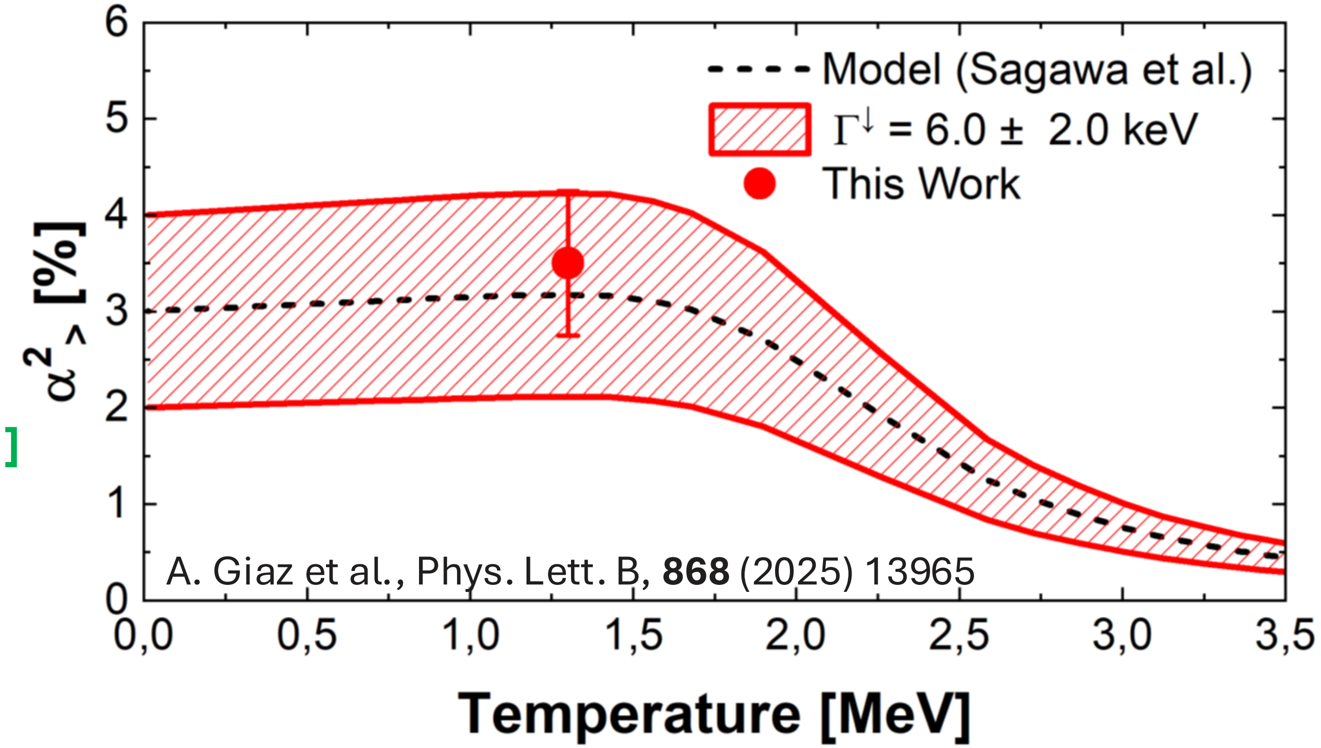

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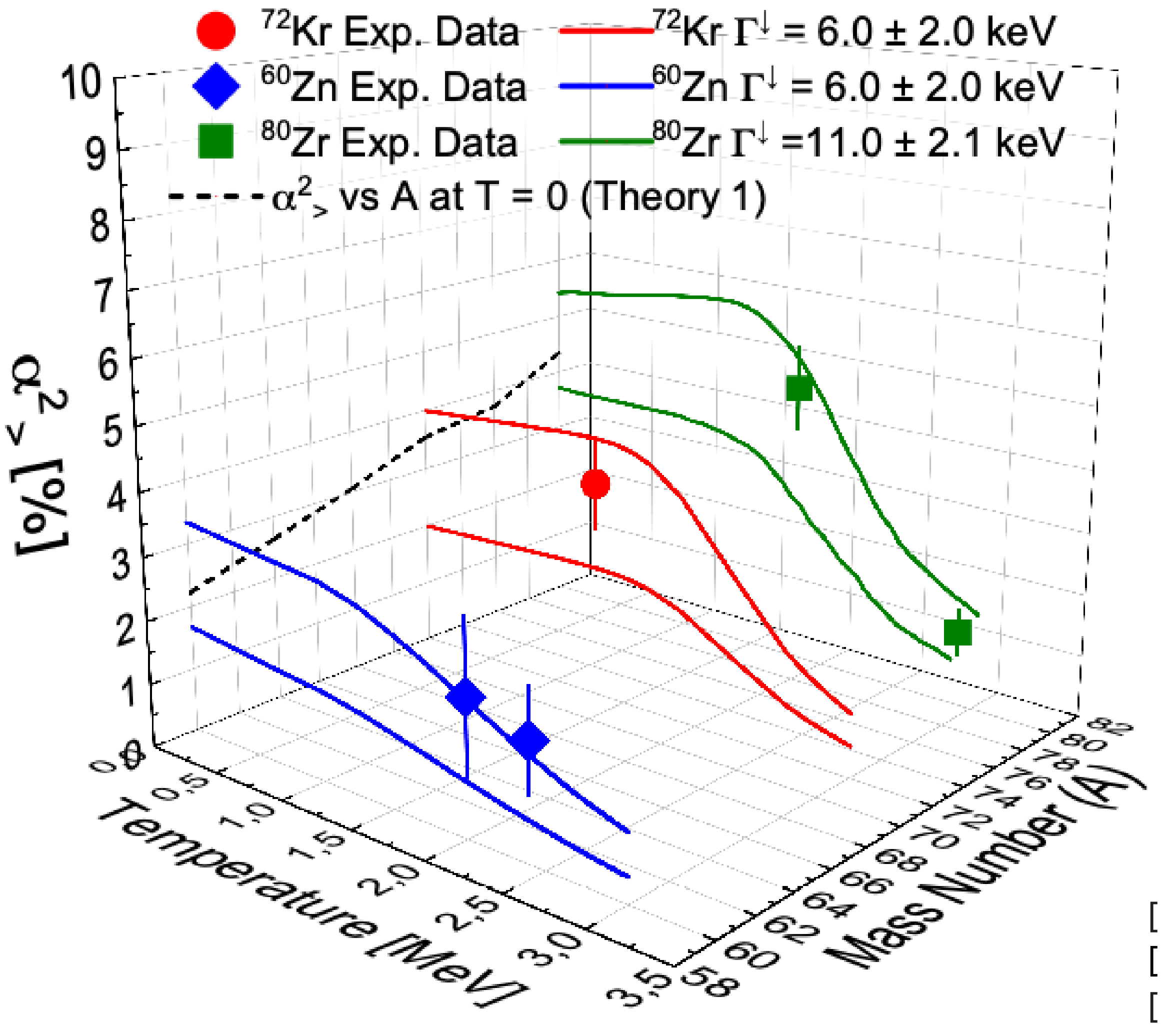

From finite temperature to zero temperature:

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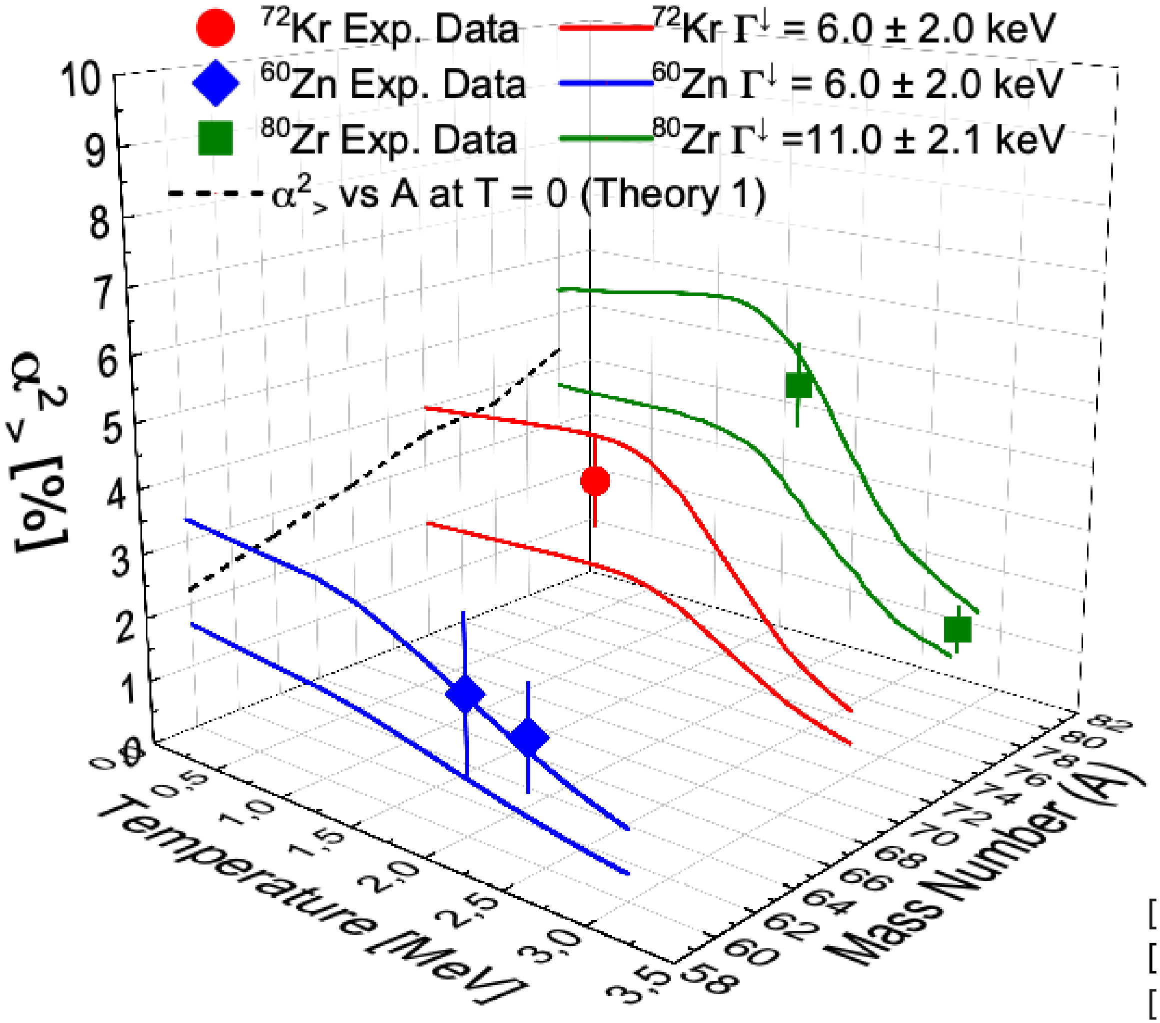

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Mixing Probability α^2 follows the expected trend both as a function of **Mass Number (A)** and **Temperature**

[1] G. Gosta et al., Phys. Rev. C **103**, (2021) L041302
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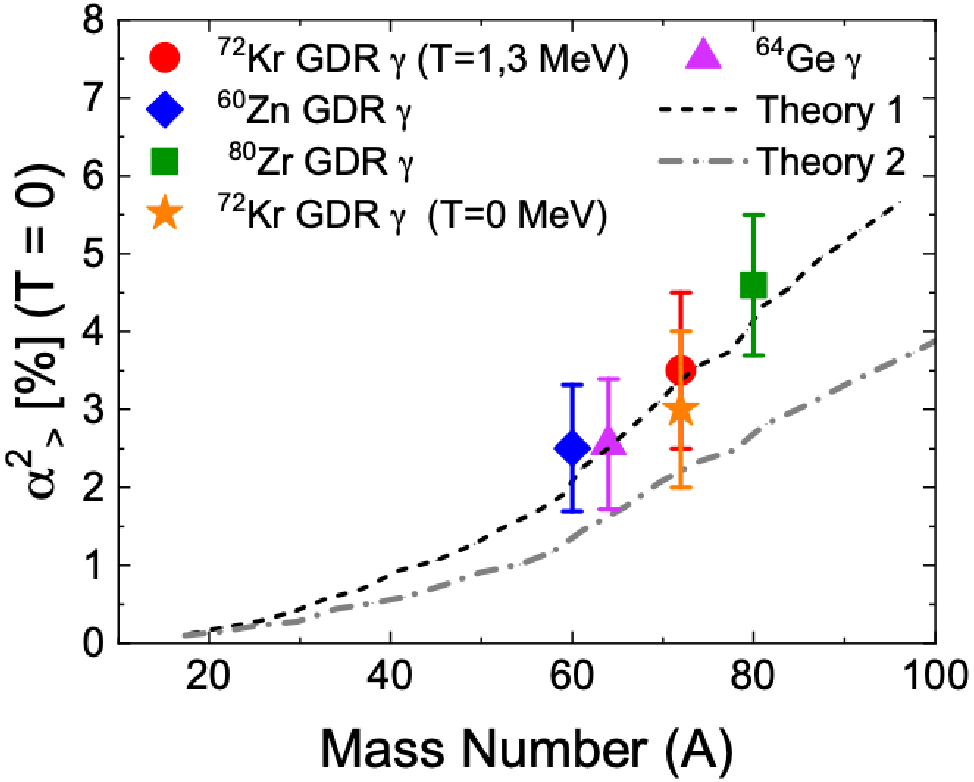

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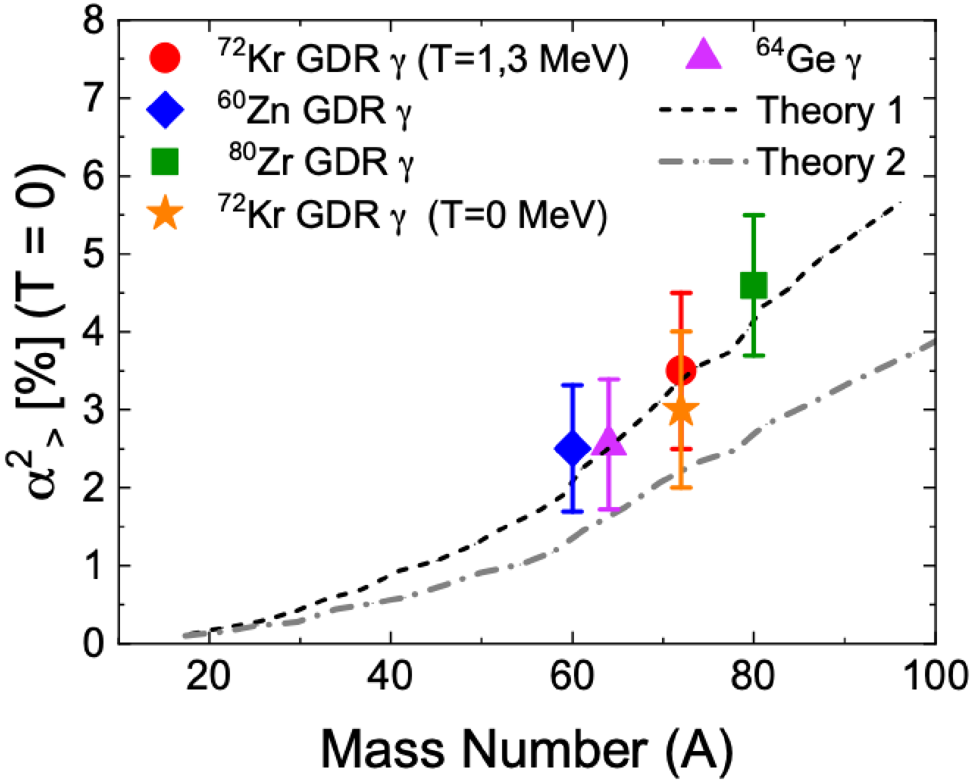
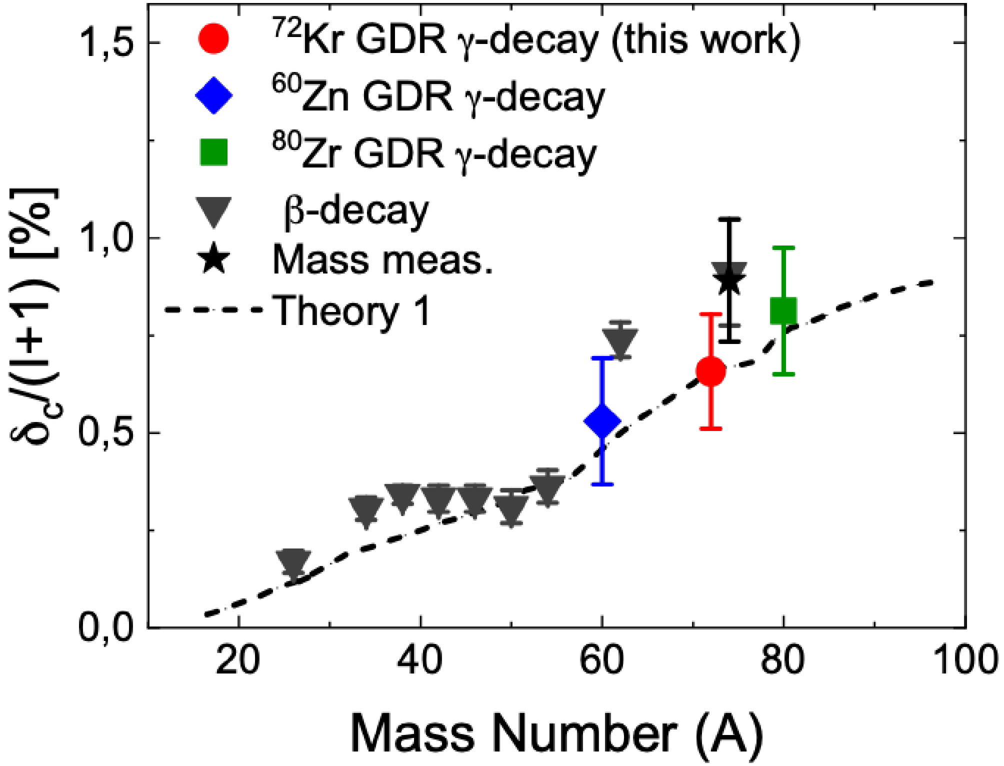


To $\delta_c = 4(I+1)\frac{V_1}{41\xi A^{2/3}}\alpha^2$ [1]

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



[1] N. Auerbach, Phys. Rev. **C 79**, 035502 (2009)

SUMMARY AND PRESPECTIVES

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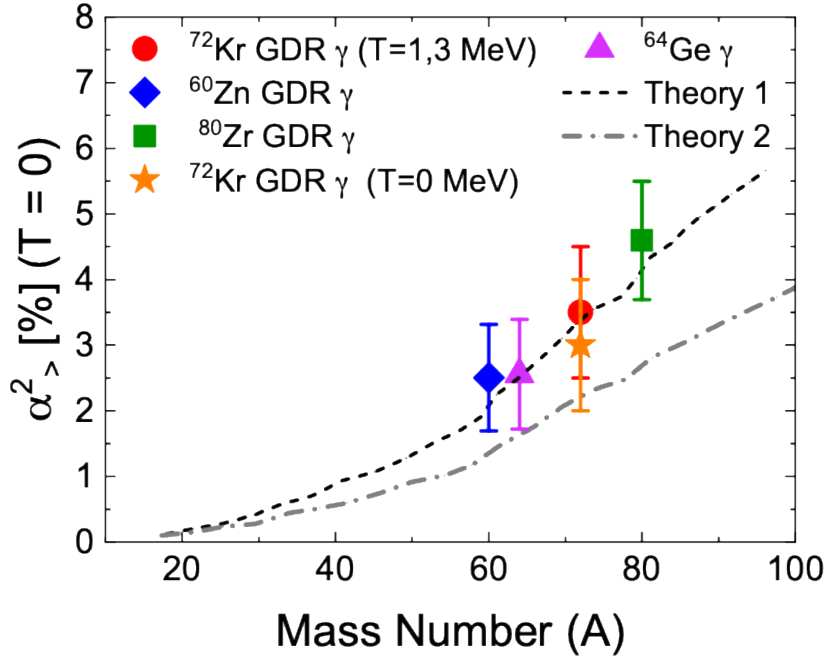

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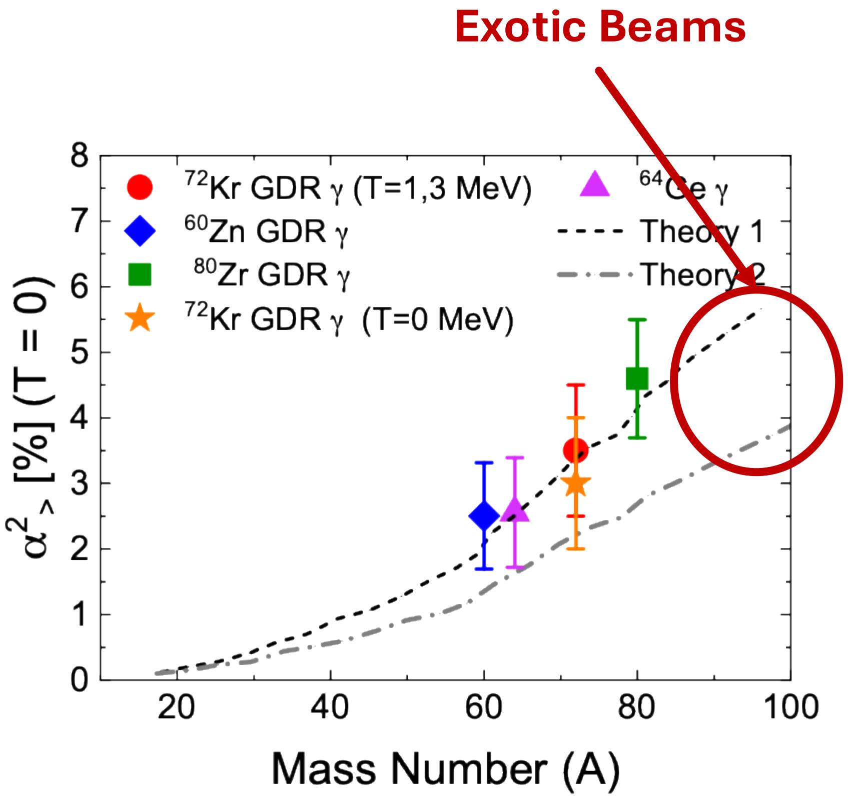
Exotic Beams

COLLABORATORS

Agnese Giaz[a], Oliver Wieland[a], Angela Bracco[b,a], Franco Camera[b,a], Soichiro Aogaki[c], Dimiter L. Balabanski[c], 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. Nită[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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[h]Institute of Experimental and Applied Physics, Czech Technical University in Prague, Husova 240/5, Prague, 110 00, Czech Republic

THANK YOU FOR THE ATTENTION!