Study of isospin symmetry in ^{80}Zr

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Outline

- Isospin mixing
- Isospin mixing using GDR γ decay
- Isospin mixing in ^{80}Zr
- Isospin mixing beyond nuclear structure
- Conclusions

The Isospin Mixing in the ground state

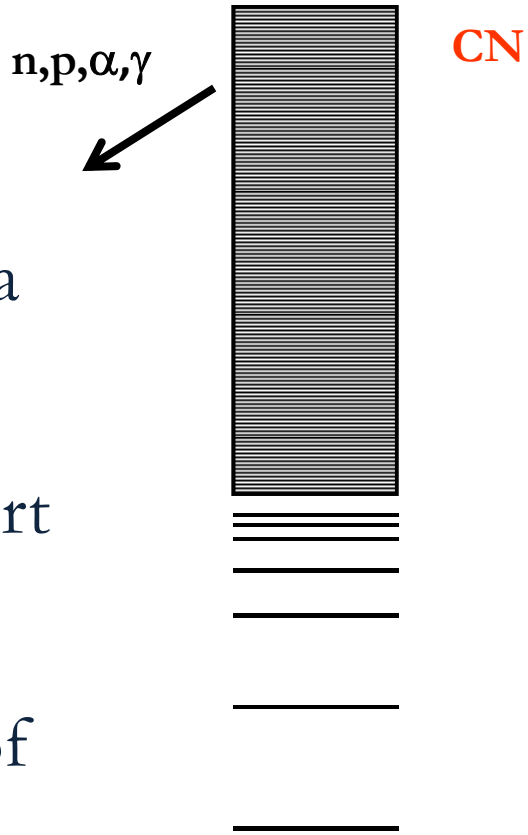
- **Isospin symmetry**: neutrons and protons can be considered as a same particle: **the nucleon**
- **Coulomb interaction** breaks this symmetry
- mixing probability in the nuclear ground state is defined as:

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

- Connection with **IAS** properties and **CKM** matrix

The Isospin Mixing at T>0

- A **CN** in an excited state has a **finite lifetime τ**
- The lifetime can be so short to not allow a complete mixing
- At high excitation energy (and thus at short lifetime) the isospin symmetry is **restored**
- Lifetime implies a **dynamical behavior** of the isospin mixing phenomenon



The Isospin Mixing at T>0

This **dynamical behavior** is descripted by the parameter α^2, defined as:

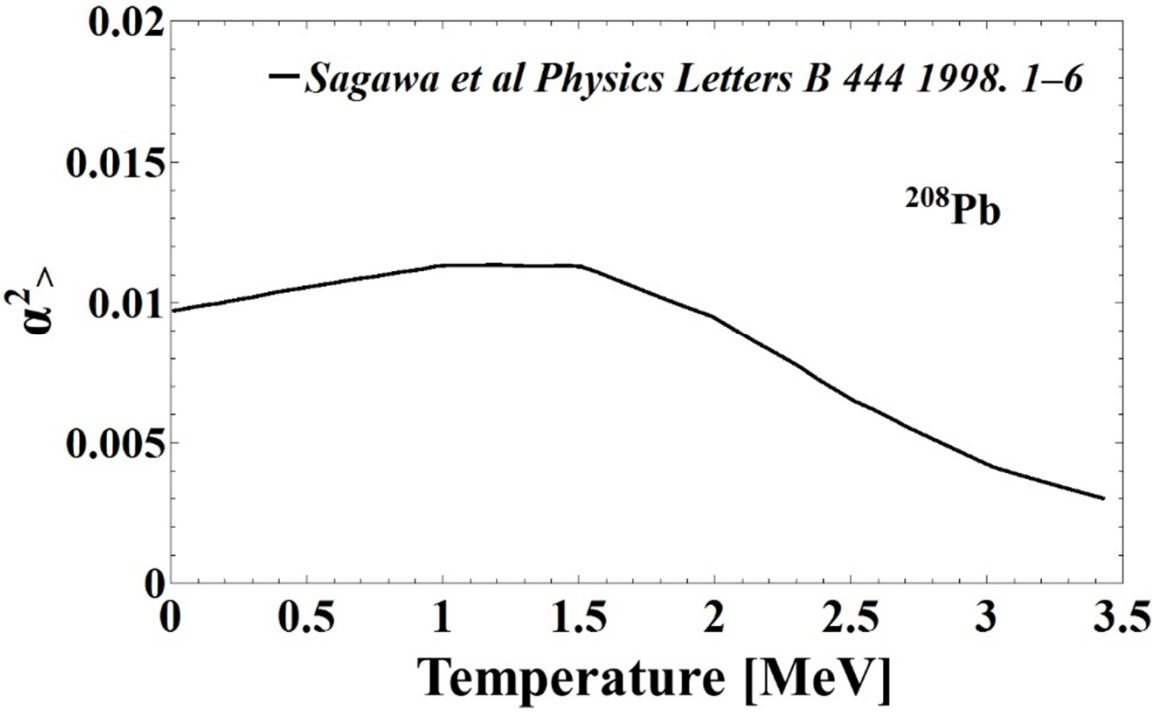
$$\alpha^2 \simeq \frac{\Gamma^{\downarrow}}{\Gamma_{CN}} \simeq \frac{\tau_{CN}}{\tau_{MIX}}$$

Coulomb spreading width → To be obtained from measurements

Compound nucleus decay width → Known from statistical decay

H.L. Harney, A. Ritcher, H.A. Weidenmuller Rev. Mod. Phys. 58(1986)607
Harakeh et al., PLB 176 (1986) *Kicinska et al., Nucl. Phys. A 36 (2005)*
Behr at al., PRL 70 (1993)

The Isospin Mixing at T>0



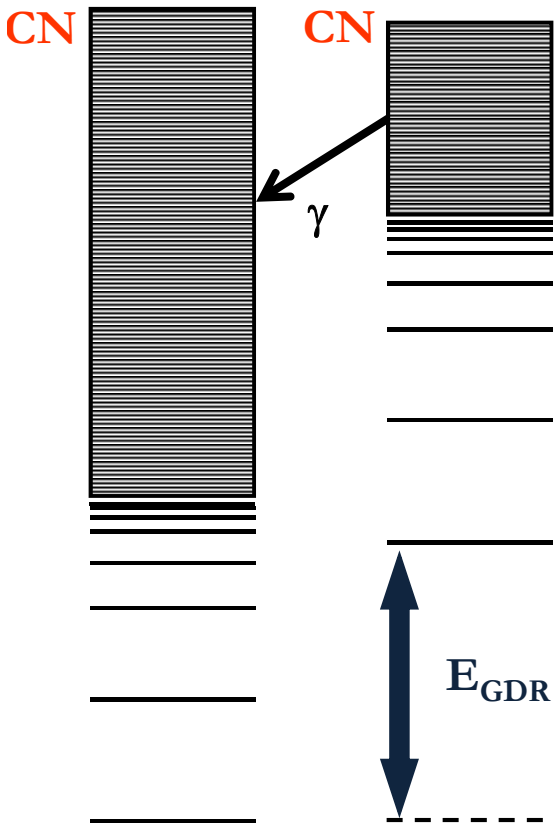
$$\alpha^2_{I_0+1} \sim \frac{\Gamma^{\downarrow}_{\mathrm{IAS}}}{\Gamma^{\uparrow}_{\mathrm{CN}}(T) + \Gamma_{\mathrm{IVM}}}$$

Colo' et al .PRC 54(1996)-M.N. Harakeh et al. Phys. Lett. B 176(1986)297 - A.Behr et al. Phys. Rev. Lett. 70(1993)3201
Sagawa et al Physics Letters B 444 1998. 1–6 - Satula et al PRL 103, 012502 (2009)

The Isospin Mixing at T>0

- In N=Z nuclei I=0
- In N=Z nuclei the **Electric Dipole transitions** in long-wavelength limit are forbidden in states with the same isospin.

GDR at Temperature > 0



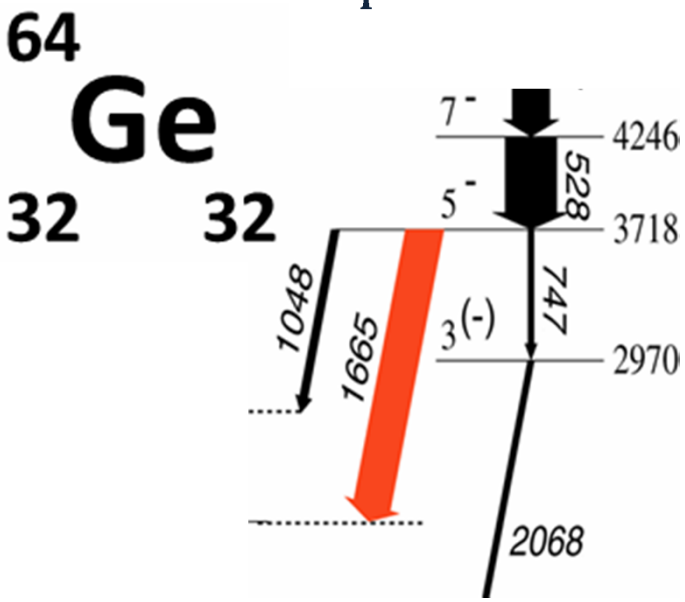
$$I_{fin} = I_{in} \pm 1$$

Selection rule:
E1 decays correspond to change of isospin

The **mixing** increases the γ decay yield

The observed **E1 strength** is a signature of the mixing

Temperature= 0

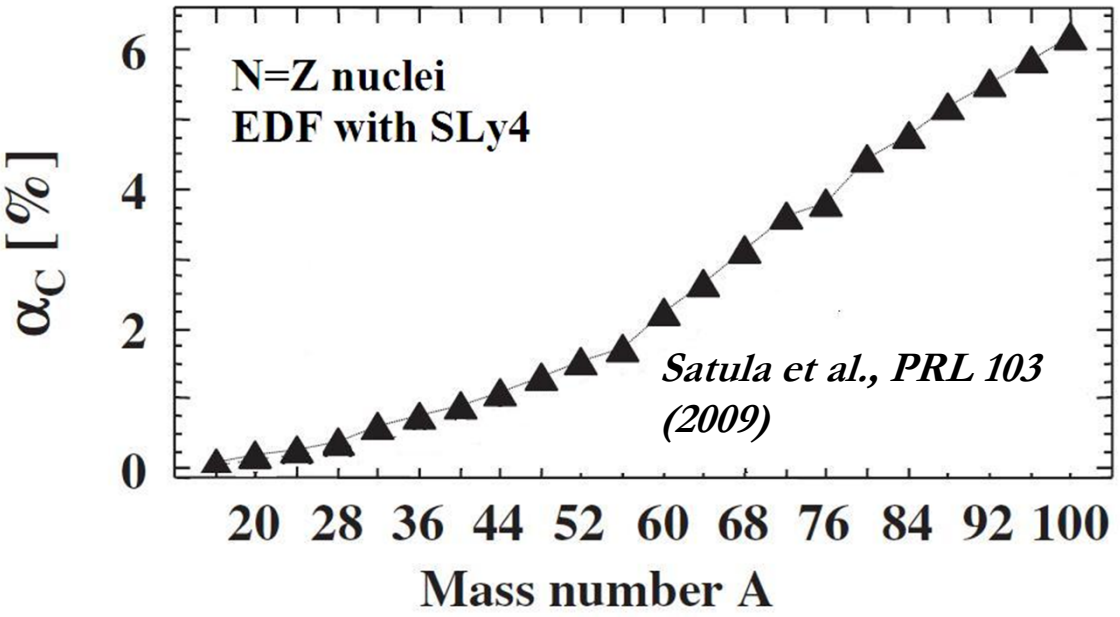


E. Farnea et al. Phys. Lett. (2002)

α^2=2.50(+1.0-0.7)%

The Isospin Mixing at T>0

Why ^{80}Zr?



- **^{80}Zr** is the heaviest N=Z Compound nucleus in the I=0 channel experimentally accessible with stable beams
- In **^{80}Zr** the isospin mixing effects are "strong"
- The theoretical predictions depend on the nuclear interaction used

Experimental technique and previous result

We form a I=0 Compound Nucleus with a heavy ions fusion reaction

$$^{40}Ca + ^{40}Ca \Rightarrow ^{80}Zr^*$$

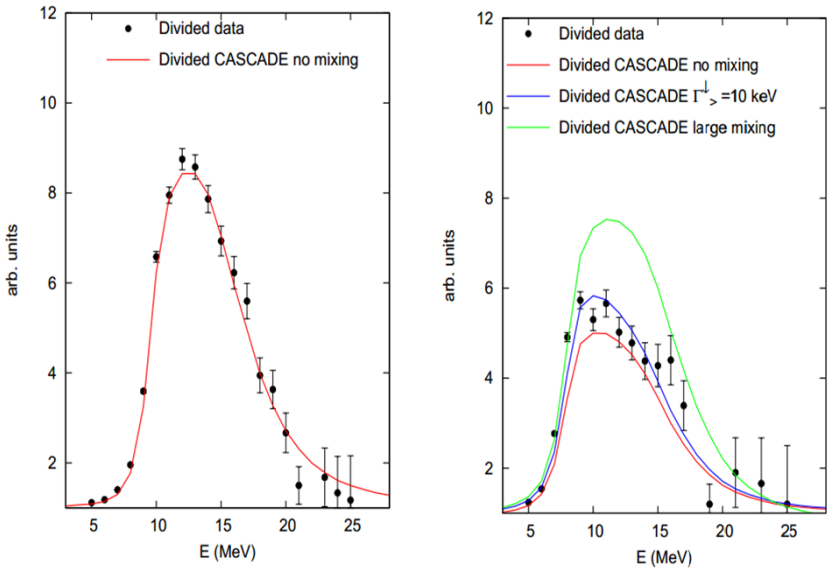
From the data fit we can extract α^2, $\Gamma^{\downarrow}$ quantity

We form a I≠0 Compound Nucleus with a heavy ions fusion reaction

$$^{37}Cl + ^{44}Ca \Rightarrow ^{81}Rb^*$$

➢We can use this reaction to determine the GDR's parameters.

GARFIELD & HECTOR (BaF_2)



$E^* = 84$ MeV $T = 3$ MeV

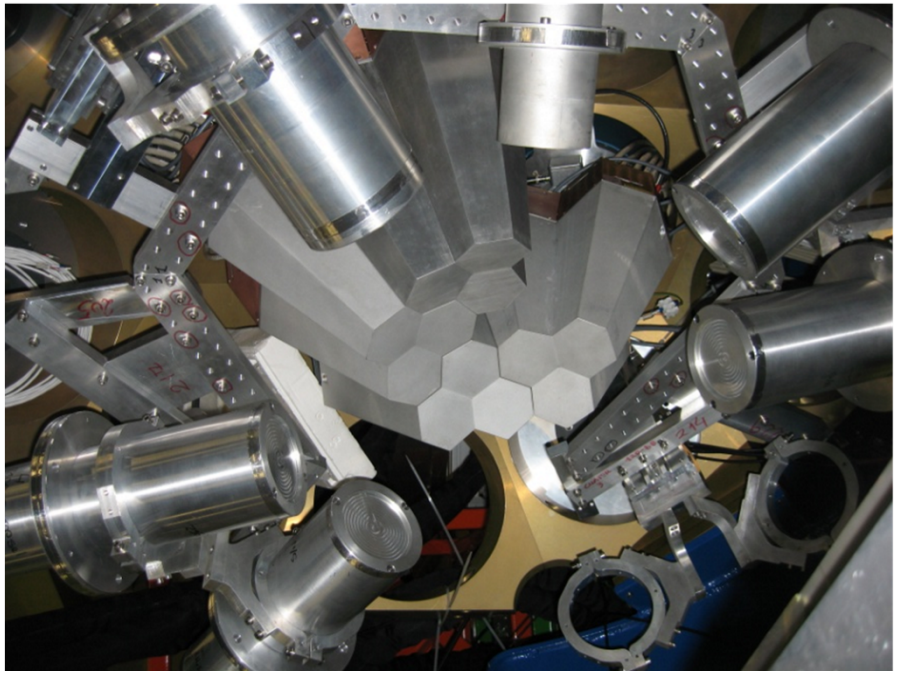
$\Gamma^{\downarrow}=10\pm3$ keV
$\alpha^2 = 0.013 \pm 0.004$

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

Measurements and Analysis

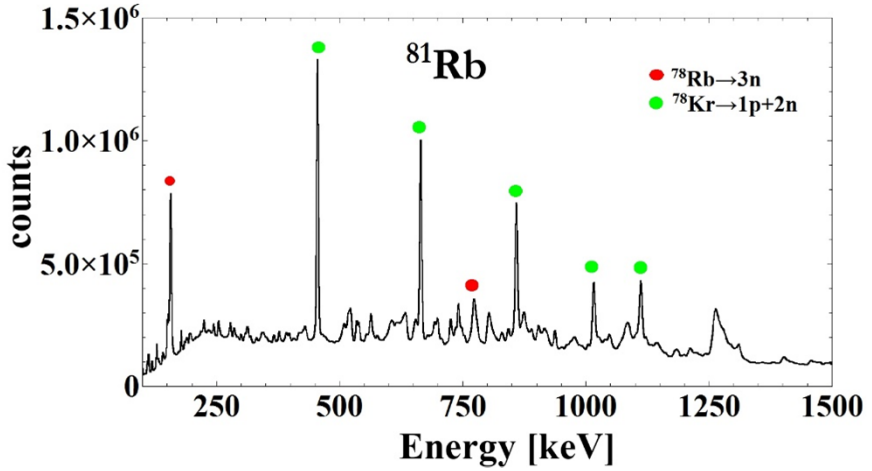
AGATA – HECTOR$^+$ array @ LNL

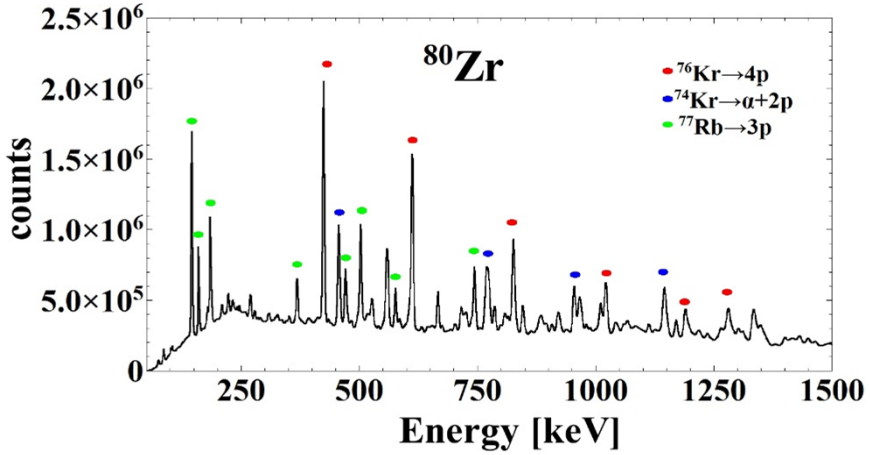
4 AGATA Clusters (12 capsules)
6 $LaBr_3$:Ce (3.5” x 8”)



$E^* = 54$ MeV $T = 2$ MeV

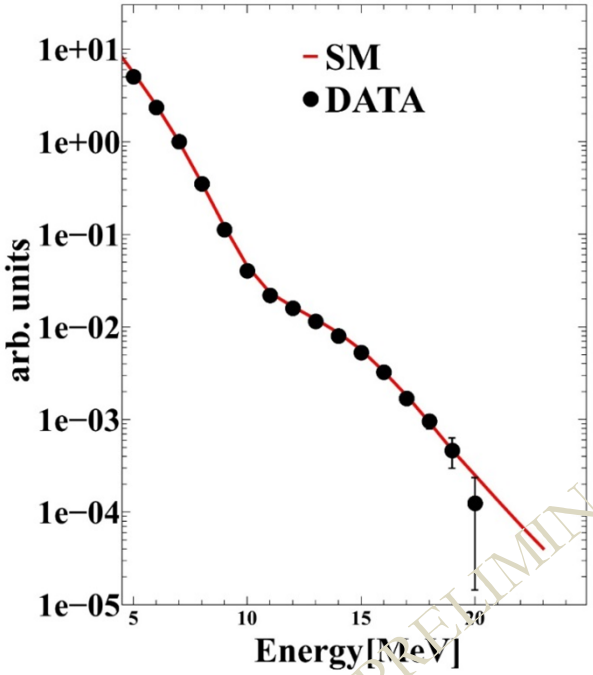
With **AGATA** we identify the evaporation residues to tune statistical model





Measurements and Analysis

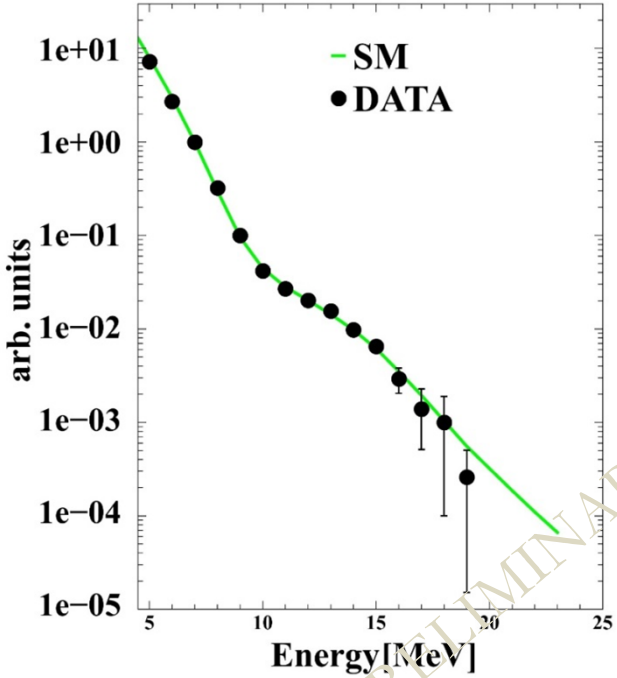
^{81}Rb–HECTOR^{+}



E_{GDR} = 16.4 ± 0.2 MeV
Γ_{GDR} = 7.0 ± 0.4 MeV
S_{GDR} (%) = 90 ± 5

➢GDR parameters are consistent with those of previous experiment as expected

^{80}Zr–HECTOR^{+}



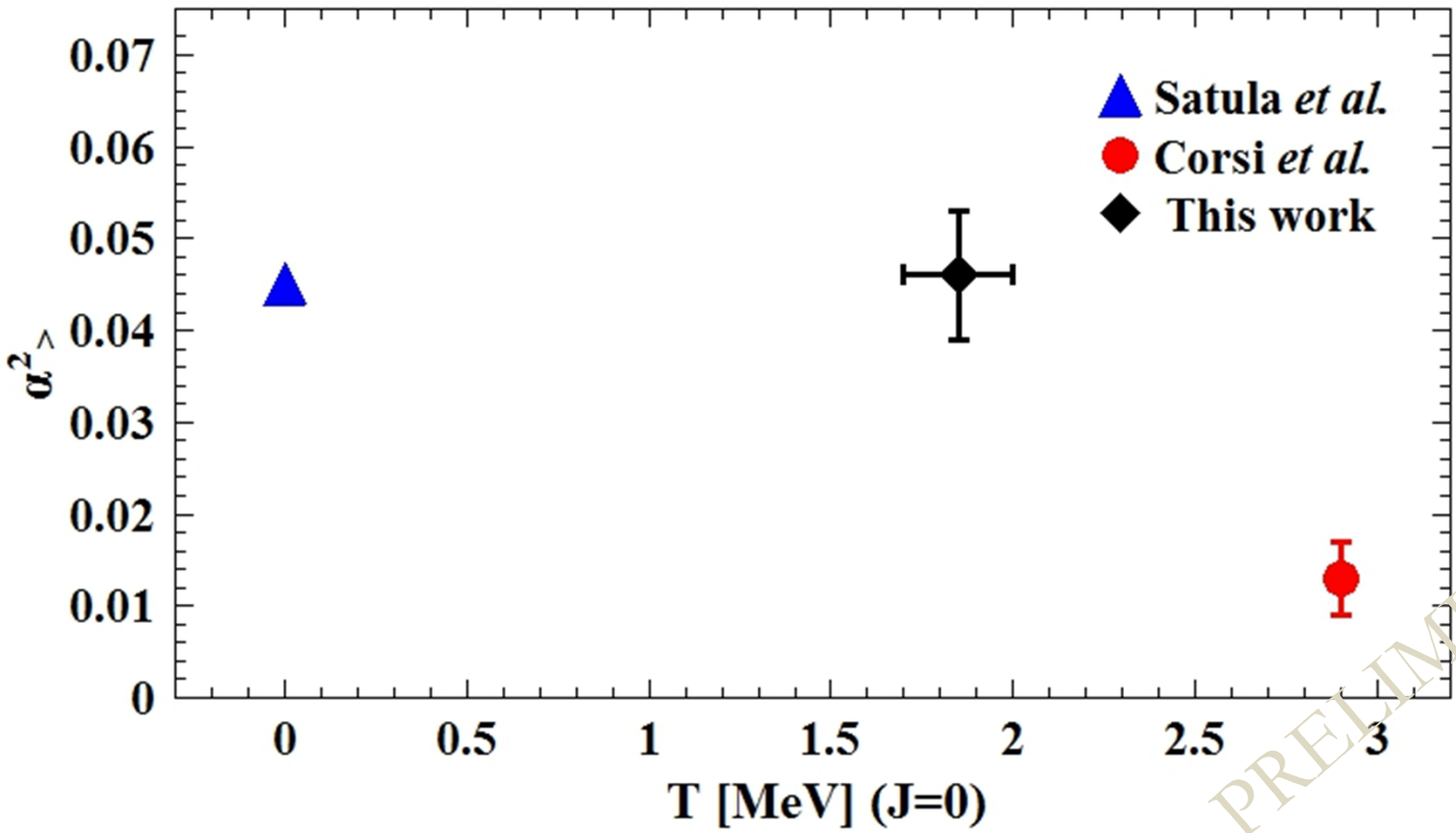
Preliminary fit result→$\Gamma^{\downarrow}$=12±3 keV

➢**$\Gamma^{\downarrow}$ is consistent (within the error bars) with that one of previous experiment.**

➢**$\Gamma^{\downarrow}$ doesn't change with temperature**

α^2=0.046±0.007

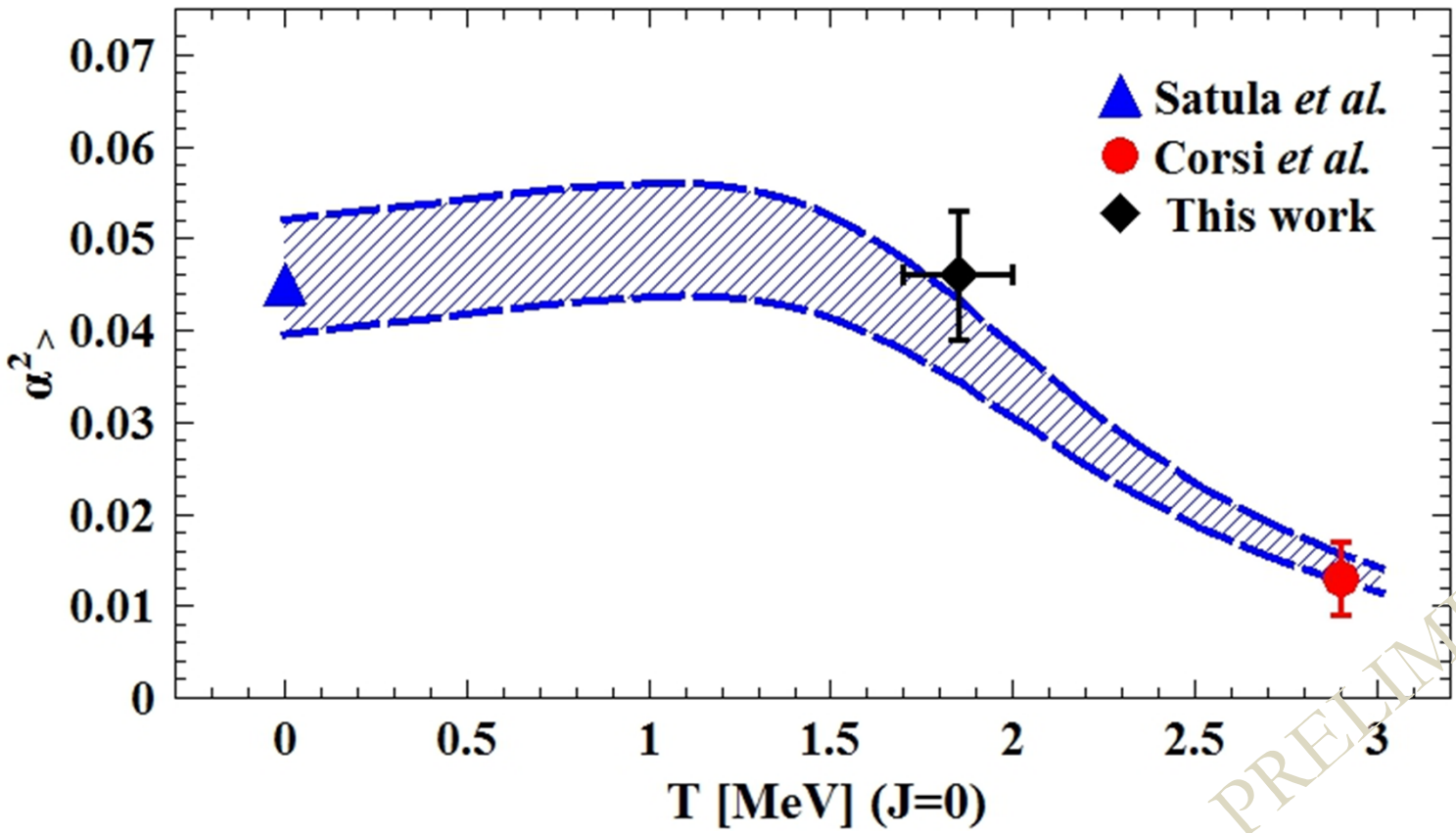
Results



The data show clearly the temperature dependence of α^2

[1] *Satula, Acta Phys.Polon. B42 (2011)*
[2] *A.Corsi et al. PRC 84, 041304(R) (2011)*

Results



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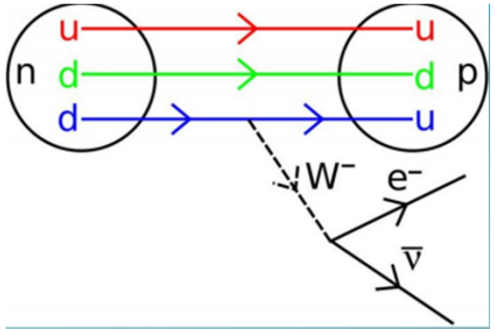
Beyond nuclear structure: CKM matrix

Superallowed Fermi transition



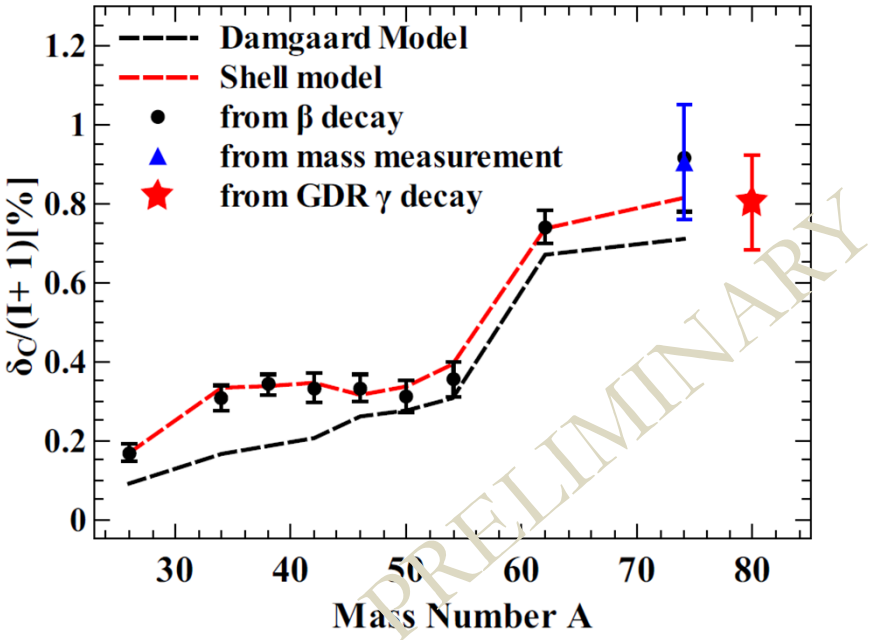
Auerbach (*PRC **79**, 035502 (2009)*) proposed:

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

Isospin mixing

$$ft = \frac{K}{|M_F|^2 G_V^2} = \frac{K}{|M_F|^2 G_F^2 V_{ud}^2}$$

$$Ft \equiv ft(1+\delta_R)(1-\delta_C)$$



I.S. Towner and J.C. Hardy PRC 82, 065501 (2010)

Conclusions

- We studied Isospin mixing at T > 0 using the GDR γ-decay as a probe
  - two dataset are available at T=2.2 and 3 MeV on ^{80}Zr
- consistent GDR parameters for ^{81}Rb
- the same value of Coulomb spreading width ($\boldsymbol{\Gamma^{\downarrow}}$) within error bar
- $\boldsymbol{\alpha^2}$ decreases with temperature
- With the theoretical help it is possible to extract the T=0 mixing from T>0 data
  - Analysis shows that the measured trend of $\boldsymbol{\alpha^2}$ follows the theoretical one.
  - From a simple analysis we obtain a value $\boldsymbol{\alpha^2}$ ~0.046 at T=0

- We shown the possibility to use $\boldsymbol{\alpha^2}$ for the estimation of isospin correction $\boldsymbol{\delta_C}$