Low-lying 1^- and 2^+ states in ^{124}Sn via inelastic scattering of ^{17}O

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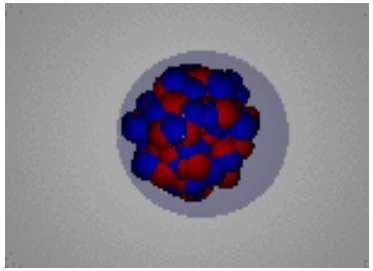
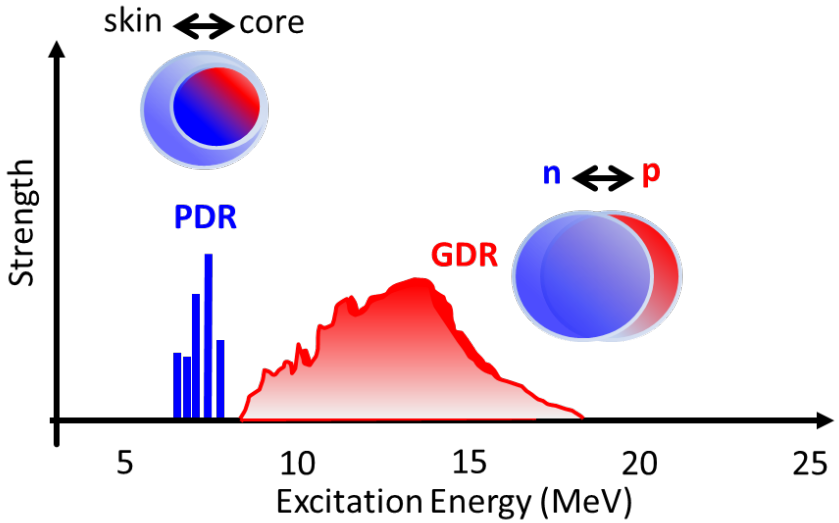
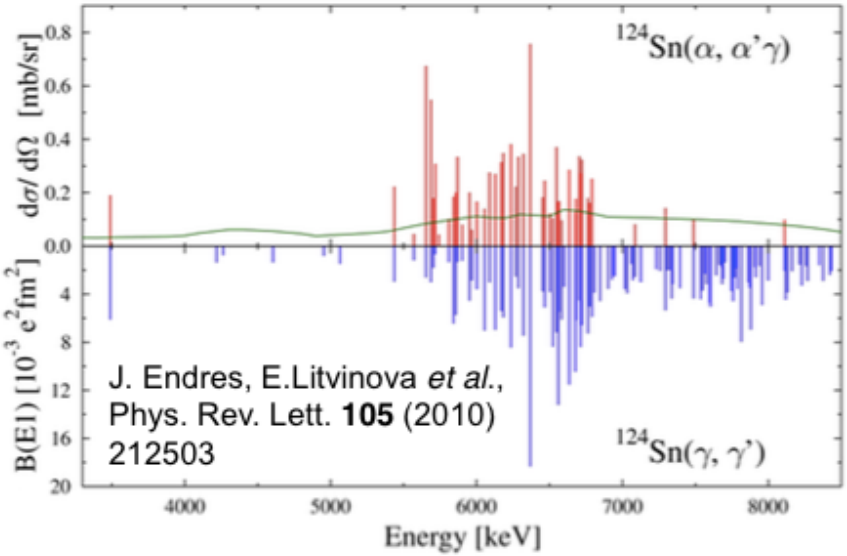
Physics Motivation: PYGMY DIPOLE RESONANCE

PYGMY DIPOLE RESONANCE:
vibration of the excess neutrons against the core



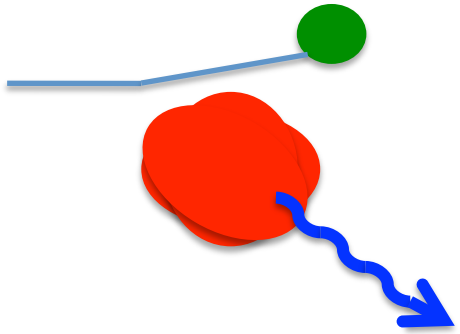




- **Selectivity in the population** of these "pygmy" states has been observed
- the **low-energy states** are of **isoscalar nature** and their transition density is peaked on the surface, while the **high-energy states** are of **isovector nature** and are associated to a transition towards the IVGDR.

❖ It is interesting to study the PDR states with isoscalar probes in different mass regions

Physics Motivation: INELASTIC SCATTERING



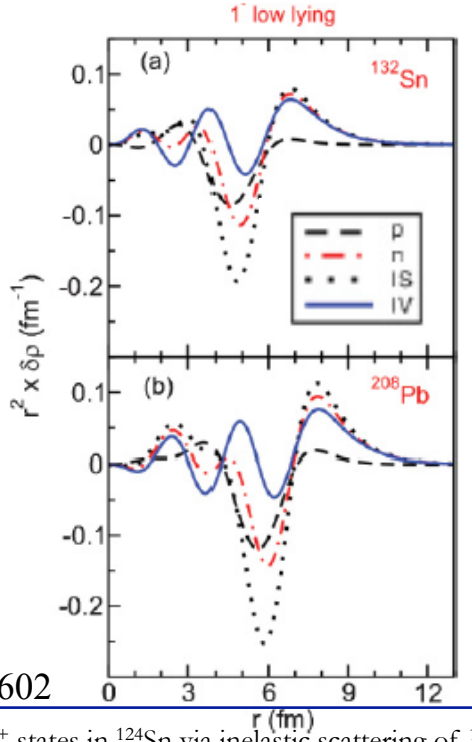
- Dominant **ISOSCALAR** excitation
- Interaction **SURFACE PEAKED (e.g. α, ^{17}O)**

Gamma decay to the g.s. – selectivity to E1

Why is it interesting to use a probe that interacts mainly at the surface?

Transition densities:

- n and p transition densities are **in phase inside the nucleus**; at the **surface only the neutron part** survives



E. Lanza et al.PRC84(2011)064602

EXPERIMENTAL TECNIQUE

Inelastic scattering of ^{17}O @ 20 MeV/u on different targets + γ-rays in coincidence

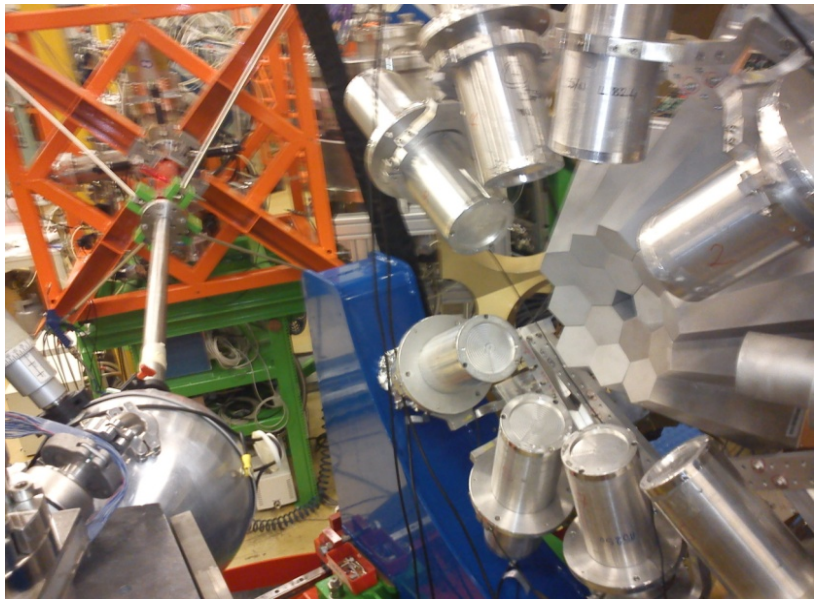
Two experiments performed at LNL:

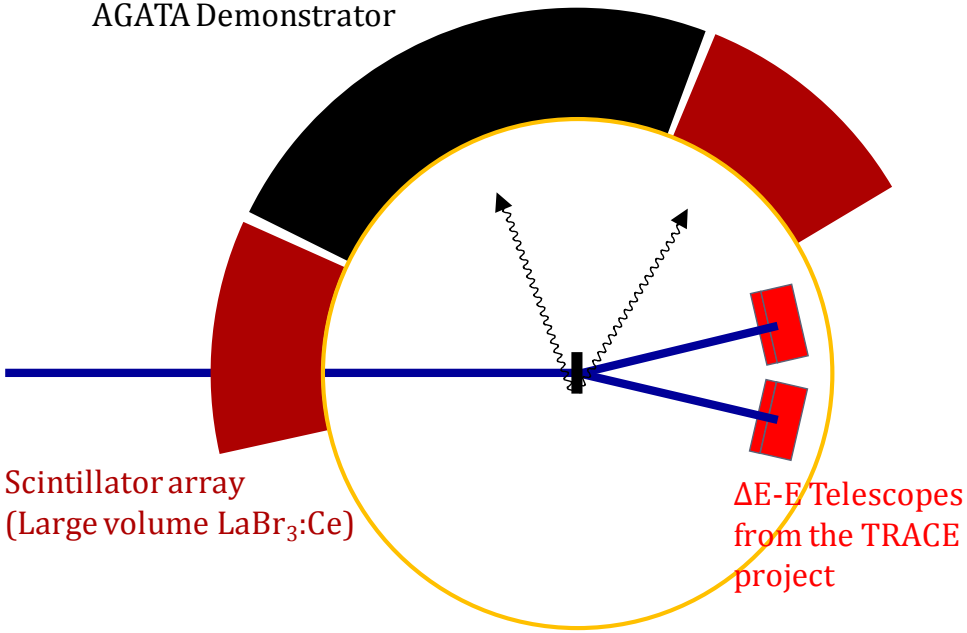
1) Inelastic scattering on **^{208}Pb, ^{90}Zr**

2) Inelastic scattering on **^{208}Pb, ^{124}Sn, ^{140}Ce**
(with improved experimental setup)

- Large cross-section for the population of the high lying states
- ^{17}O is loosely bound (S_n = 4.1 MeV)
- Clean removal of projectile excitation
- ^{124}Sn – target thickness 3 mg/cm^2

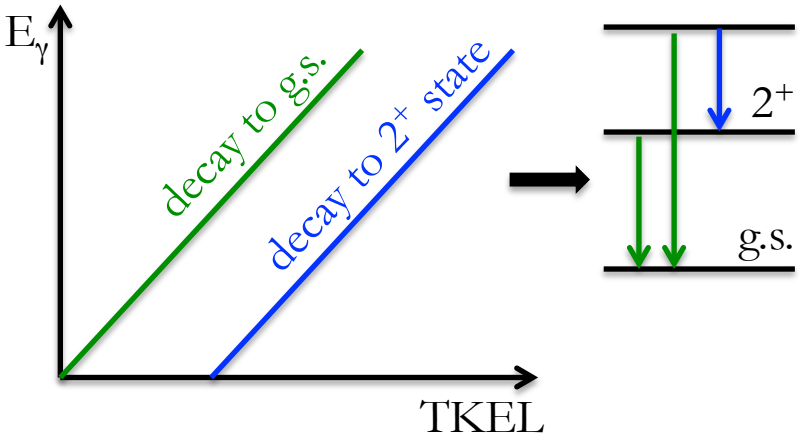
Experimental set-up





PYGMY STATES

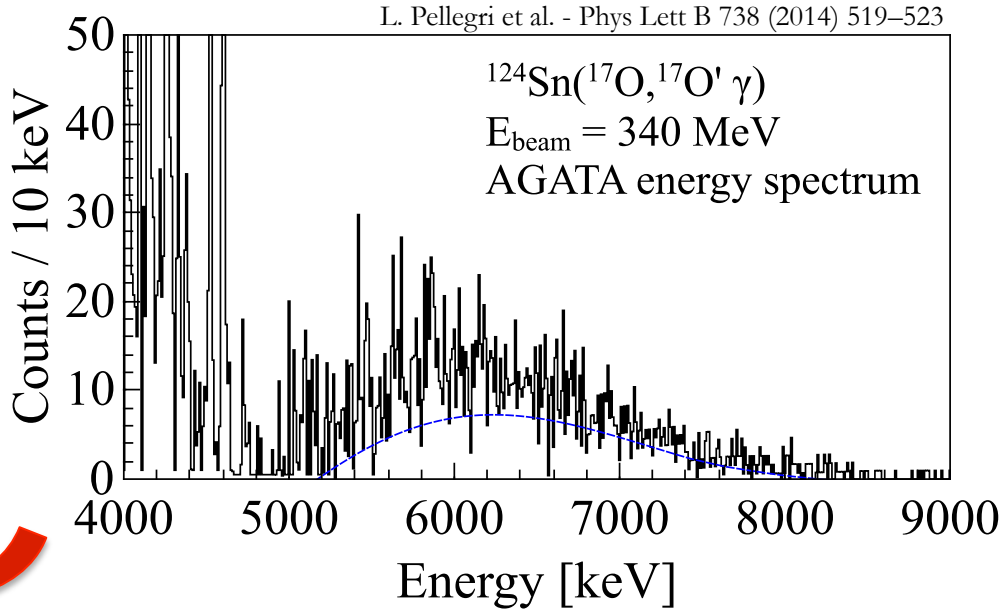
Diagonal cut on E_γ vs TKEL ⇒ Enhancement of ^{124}Sn g.s. decay



AGATA:

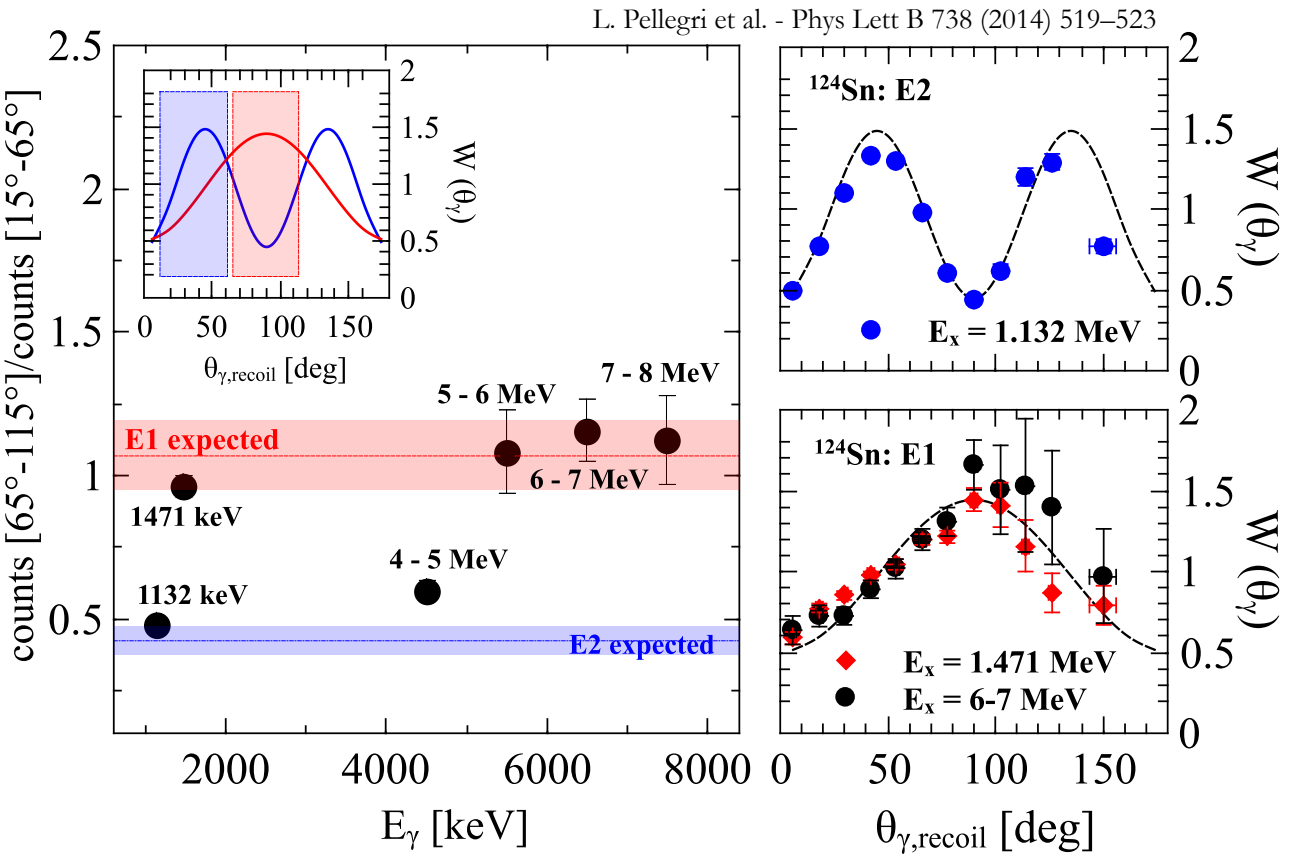
- ^{17}O scattering channel
- Select E_γ = TKEL
- Doppler correction for recoil motion
- Background subtraction

- **Large fragmentation of the dipole strength**
- **States above 7 MeV not populated**



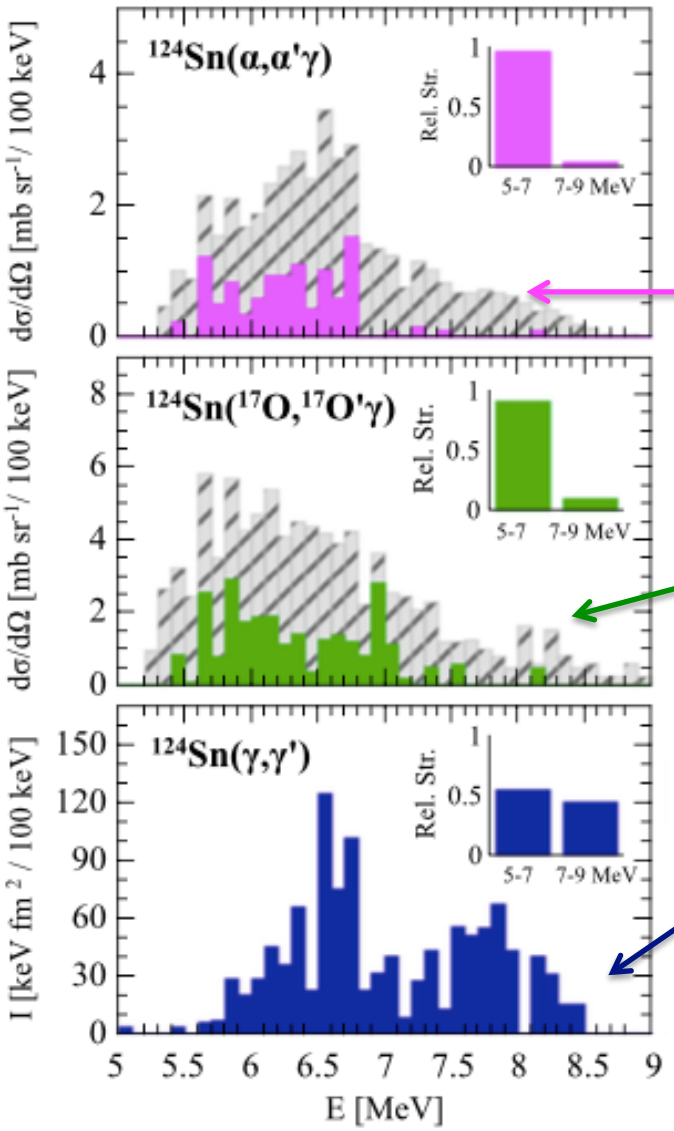
ANGULAR DISTRIBUTION

Angular Distribution of gamma rays obtained exploiting position sensitivity of AGATA and Silicon detectors → almost a continuous pattern



Pygmy region shows E1 character

NATURE OF THE PDR



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Comparison with the results of the excitation of the pygmy states with **3 different probes :**

$(\alpha, \alpha' \gamma)$ at 136 MeV - isoscalar character

J. Endres et al., Phys. Rev. C 85 (2012) 064331

(^{17}O , ^{17}O' γ) – nearly isoscalar character

Some missing strength above 7 MeV

Similar behaviour of $(\alpha, \alpha' \gamma)$

K. Govaert et al., Phys. Rev. C57, 2229 (1998)

(γ, γ') - probing the entire nuclear volume

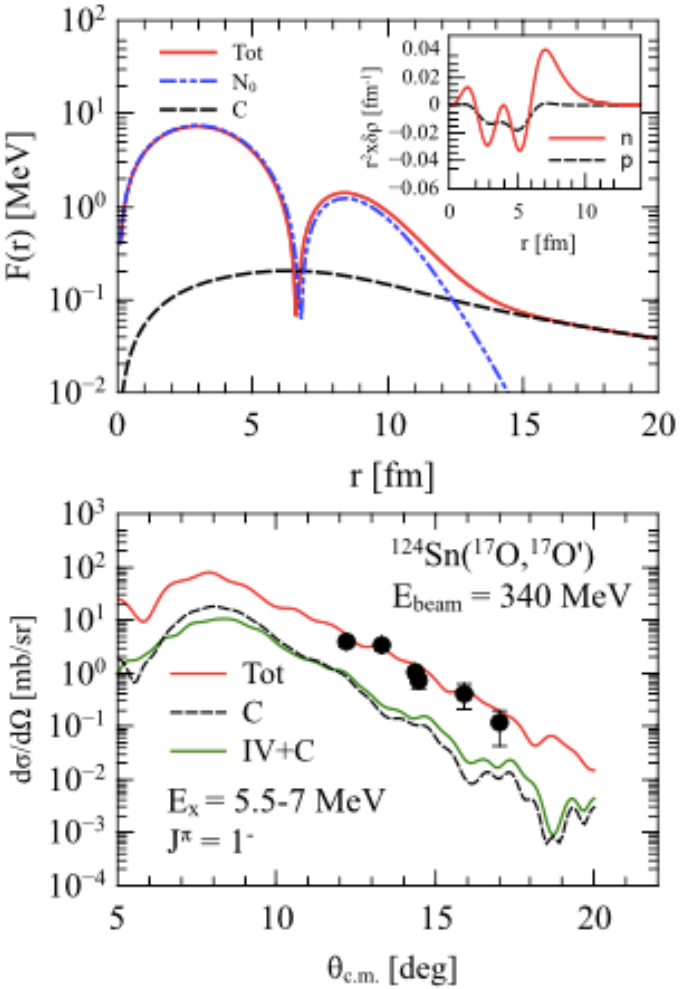
- Evidence for **isoscalar character for 5<E<7**
- **7<E<9 stronger isovector character**

CROSS SECTIONS FOR THE PYGMY STATES

DWBA calculations performed with **only the isovector form factor** with the B(E1) measured in electromagnetic excitation → **The calculations account only for the 10% of the measured yield**

Main contribution comes from **the isoscalar nuclear part**

DWBA calculation performed using a **microscopic form factor based on the transition density** obtained with a microscopic model (RQTBA)



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the value of the ISEWSR strength is 1.5(0.2)% for the sum of the measured discrete states in the interval 5.5–7 MeV.

PYGMY QUADRUPOLE RESONANCE?

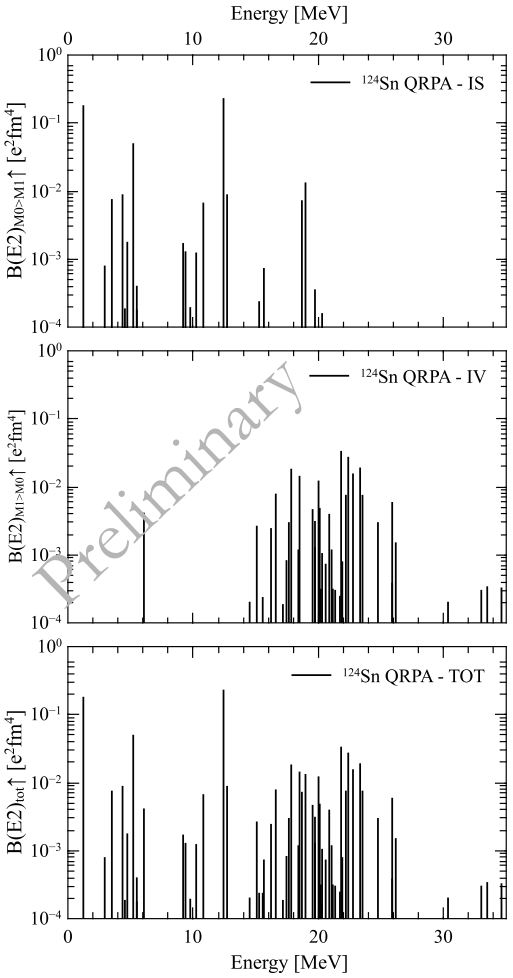
Is the presence of a neutron or proton skin affecting excitations of other multipolarities and vice versa?

Theoretical predictions (using HFB and QRPA approaches) for Tin isotopic chain show a **concentration of low-energy electric quadrupole strength** located much below the Isoscalar Giant Quadrupole Resonance (ISGQR) → **Pygmy quadrupole resonance (PQR)?**

Features:

- the microscopic structure of the QRPA 2^+ **states is predominantly of neutron character**
- **Increase of the low-energy B(E2)** strength with neutron number
- **Change from a neutron PQR to a proton PQR** in the isotopes lighter than ^{104}Sn, similarly to the PDR case

N. Tsoneva et al. - Phys Lett B 695 (2011) 174–180



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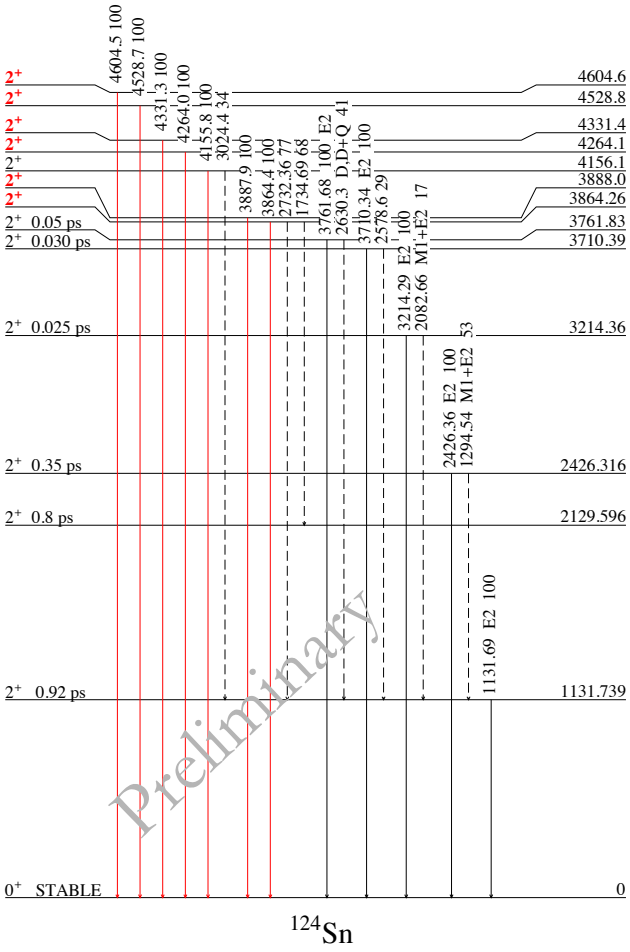
2^+ STATES OBSERVED

Experimentally, we have observed several 2^+ states below the neutron separation energy



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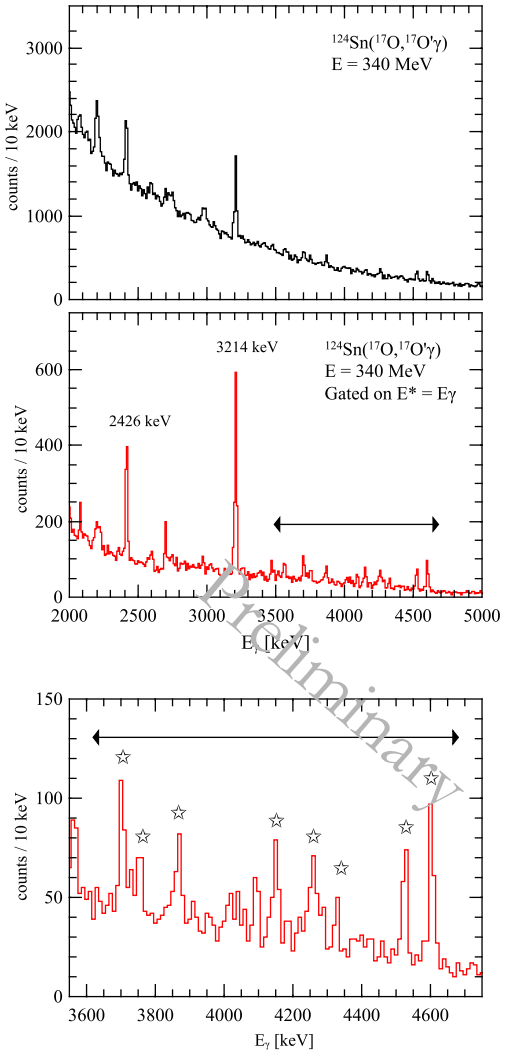
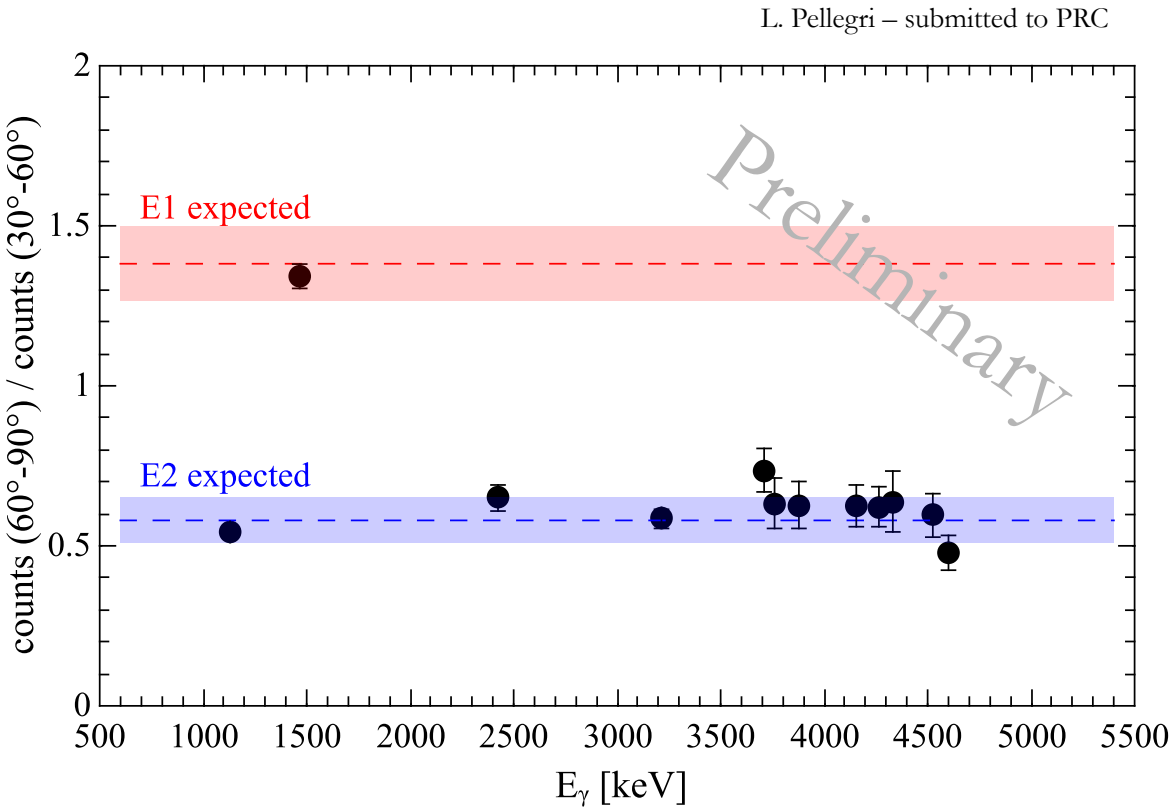


MULTIPOLARITY OF THE 2^+ STATES

The measurement of the γ decay of these observed states allowed to **assign a well-defined multipolarity** for the first time.

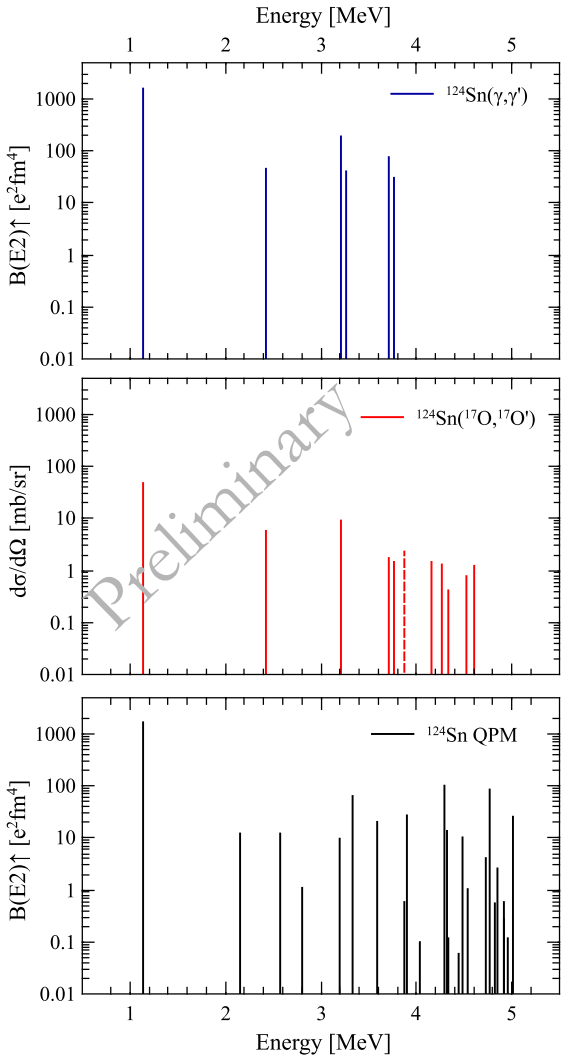


The unknown transitions are of electric quadrupole multipolarity

COMPARISON WITH THE CALCULATIONS

- Presence of a **number of 2^+ states grouping together in the energy region 3-5 MeV** supporting the prediction of the HFB+QPM model.
- This quadrupole strength clustering appears to be **similar to the known Pygmy Dipole Resonance** at 5-7 MeV.
- The microscopic analysis of these 2^+ states reveal that they have a unique **structure closely connected with excitation of the neutron skin**

First **evidence for excitation of pygmy states of quadrupole character** in ^{124}Sn and thus that the neutron skin can also have vibrations of quadrupole type.



L. Pellegri – submitted to PRC

SUMMARY

Investigation of <u>the isospin character of low-lying 1^- states</u> in ^{124}Sn in the region below the neutron binding energy:

- The data are in remarkable agreement with a previous experiment using the $(\alpha,\alpha'\gamma)$ inelastic scattering reaction showing a **different character for these pygmy states.**
- This experiment provided the **isoscalar strength distribution of the pygmy states**.
- From the comparison between DWBA analysis performed with a microscopic form factor and the measured cross sections one can deduce that **the pygmy states ^{124}Sn are associated with the excitation of surface neutrons, mainly those in the neutron skin.**

Investigation of <u>low-lying 2^+ states</u> in ^{124}Sn in the region below the neutron binding energy:

- **A group of 2^+ states with excitation energy at 3-5 MeV** for which only the energy (and not the spin) was previously known was identify.
- **The spin assignment was unambiguously made** via the measurement of the angular distribution of the γ rays de-exciting these states.
- **Evidence for excitation of pygmy states of quadrupole character** in ^{124}Sn and thus that the neutron skin can also have vibrations of quadrupole type.

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Thank you for the attention