PYGMY RESONANCE IN ^{140}CE :
FIRST MEASUREMENT USING NEUTRON INELASTIC SCATTERING

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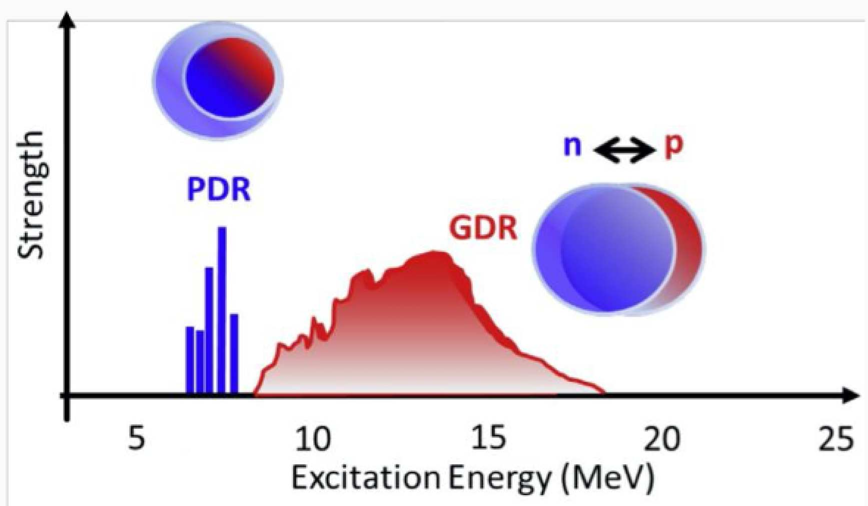
The Pygmy Dipole Resonance

Giant resonances : collective excitation modes of nuclei, characterized by the quantum numbers of the transition [1, 2] :

- The multipolarity ΔL : the $\Delta L = 1$ mode is called **dipole**, and corresponds to oscillations of proton and neutron fluids in the nucleus.
- The isospin ΔT : for $\Delta T = 0$ (resp. $\Delta T = 1$), neutrons and protons oscillate in phase (resp. in opposite phase), the mode is called **isoscalar** (resp. **isovectorial**).

Pigmy Dipole Resonance (PDR) [3] :

- Additional dipole strength at low energy (around neutron separation energy threshold)
- Characteristic of neutron-rich nuclei
- Macroscopic interpretation : vibration of a symmetric core (with $N = Z$) against a neutron skin.

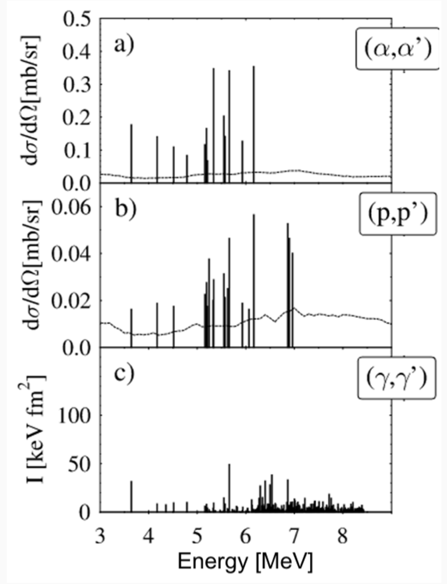


Case study : ^{140}Ce

- $N = 84$, $Z = 56$
- Pygmy region : 4-9 MeV

Results from the study of the PDR using inelastic scattering experiments in ^{140}Ce are shown [4].

Depending on the probe, different states are populated.



⇒ New probes are needed to resolve the complexity of the isospin character of the PDR, and to refine the comprehension of the PDR.

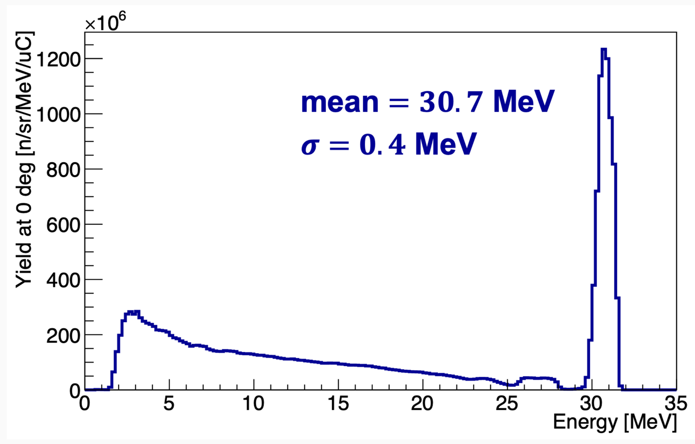
The neutron : a new complementary probe

It is the first time that the PDR is probed with neutrons.

✓ Elementary probe in nuclear physics ✓ No Coulomb corrections needed

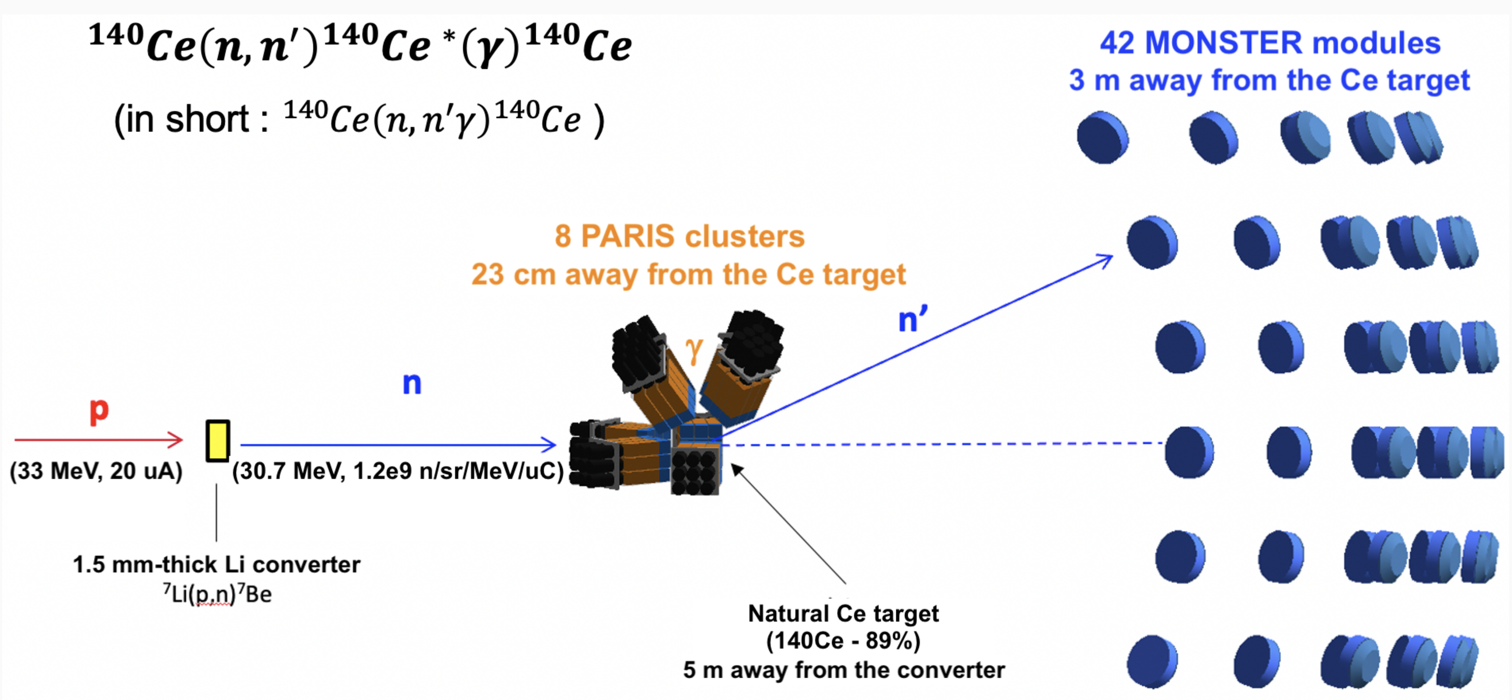
✓ More sensitive to the role of protons : complementarity with the proton probe (more sensitive to neutrons)

Made possible by the Neutrons For Science (NFS) facility at GANIL-SPIRAL2 that generates neutron beam at 31 MeV with high intensity [5].
(neutron yield measured during the experiment : 1.2e9 n/sr/MeV/μC at 30 m).

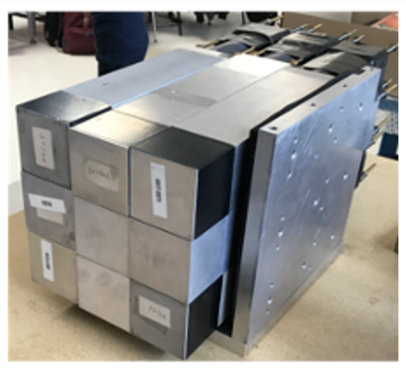


The PARIS-MONSTER setup

The experiment was conducted in September 2022 at the NFS facility at GANIL-SPIRAL2.

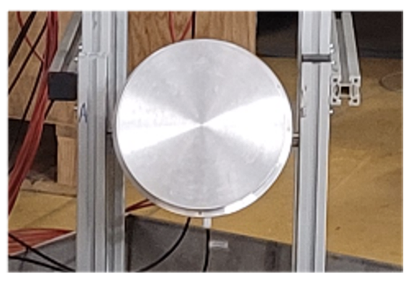


A cross section of ∼ 0.2 mb is expected for the inelastic scattering channel.



PARIS Clusters : crystal scintillators for high energy γ detection

- 8 clusters of 9 phoswiches, 23 cm away from the target.
- CeBr / LaBr + NaI crystals.
- Energy resolution (LaBr) : 3.5% at 4.4 MeV - 1.8% at 9 MeV.
- Time resolution : $\sigma \sim 400$ ps.
- Efficiency : ∼ 3% in the PDR region.



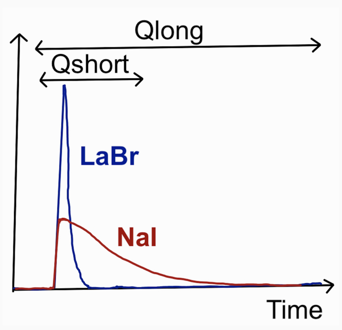
MONSTER modules : liquid scintillators for neutron detection

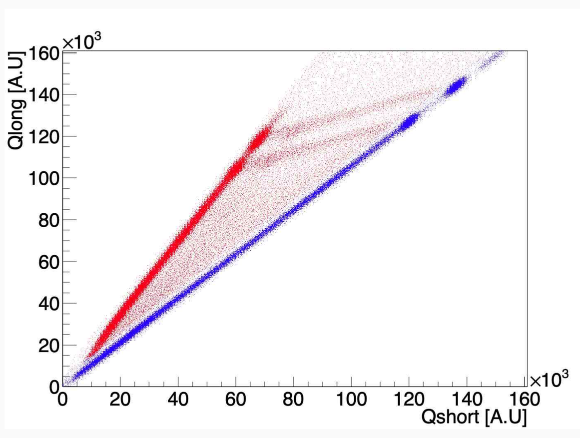
- 7 structures of 6 modules, 3 m away from the target.
- Time resolution : 700 ps ⇒ Time Of Flight method.

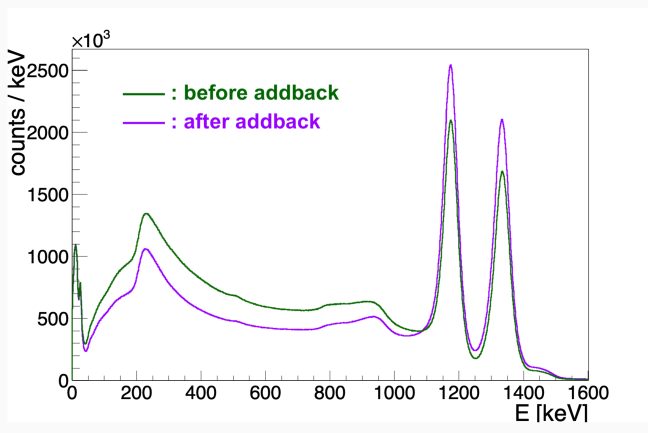
PARIS calibration

The initial stages of the data analysis were focused on the calibration of the PARIS detectors.

Pulse Shape Discrimination (PSD) in the phoswich
The two crystals in the phoswich have to be calibrated separately. To do so, a preliminary step was the discrimination of events in each crystal. This was done using the PSD method.





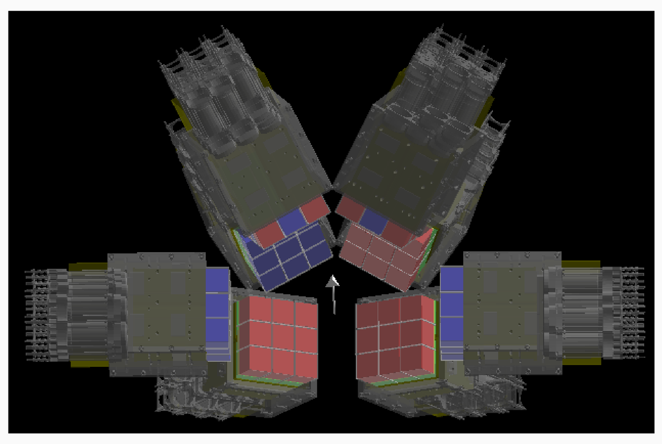


Addback procedure in the cluster
The energy of incident γ rays is reconstructed with the addback technique using:

(i) a time window : $|\Delta t| < 2$ ns
(ii) a spatial condition : neighbour phoswiches share a side or a diagonal

Ongoing work

➤ **Efficiency simulations for PARIS detectors**
Performed with Geant4, with the SToGS package.



➤ **MONSTER detectors calibration**
Using as well a PSD, here to disciminate between γ and neutrons.

References

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[5] *X. Ledoux et al., Eur. Phys. J. A* ***57****, 257 (2021).*