

Imaging the Pygmy Dipole Resonance with neutrons at NFS/GANIL: $^{140}\text{Ce}(n,n'\gamma)^{140}\text{Ce}$

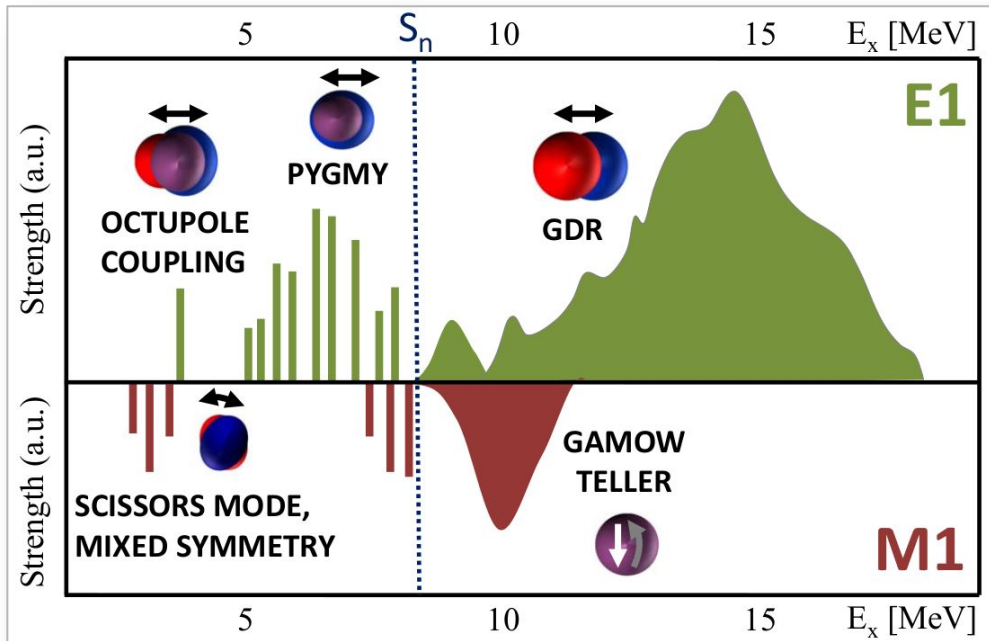
Iolanda Matea Macovei (IJCLab)
Paris-Saclay University & IN2P3/CNRS



Dipole Strength Distribution in Nuclei

γ -nucleus interaction is dominated by the dipole ($L=1$) response of the nucleus

(Andreas Zilges)

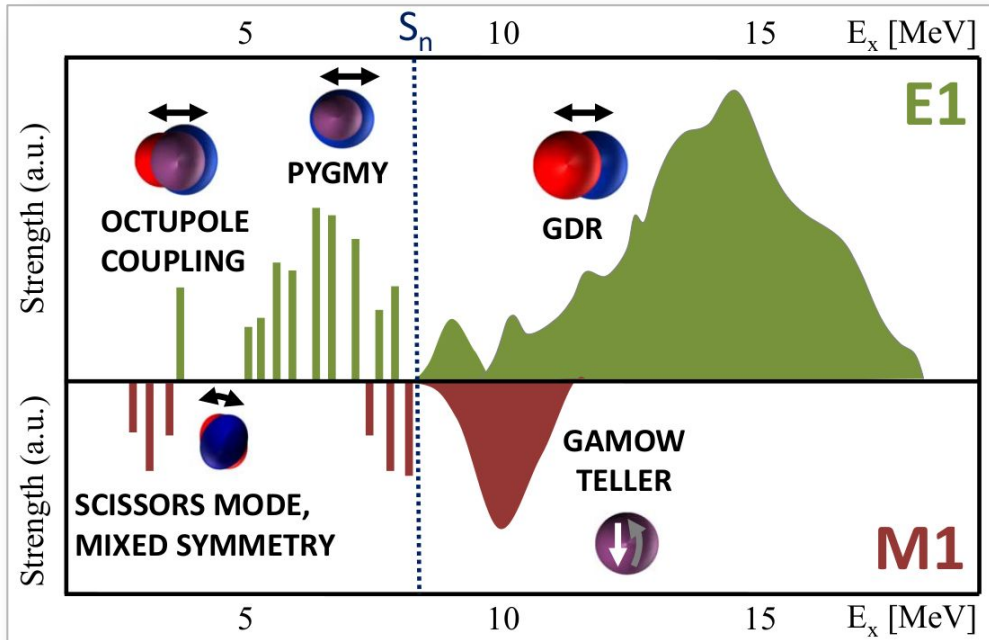




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→ **GDR**

E1

~100% of E1 strength in IV-GDR

smooth behaviour with A

iso-vector (first order), iso-scalar (second order)

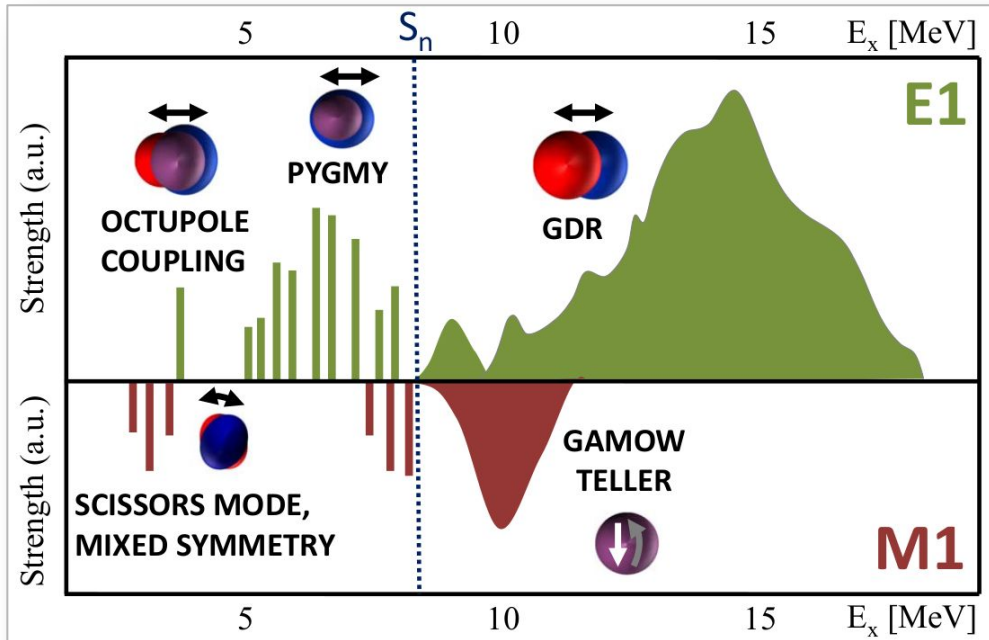
IV-GDR : most studied, proton vs neutron fluids oscillations



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→ GDR

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smooth b
iso-vector
IV-GDR : 1

→ PYGMY (PDR)

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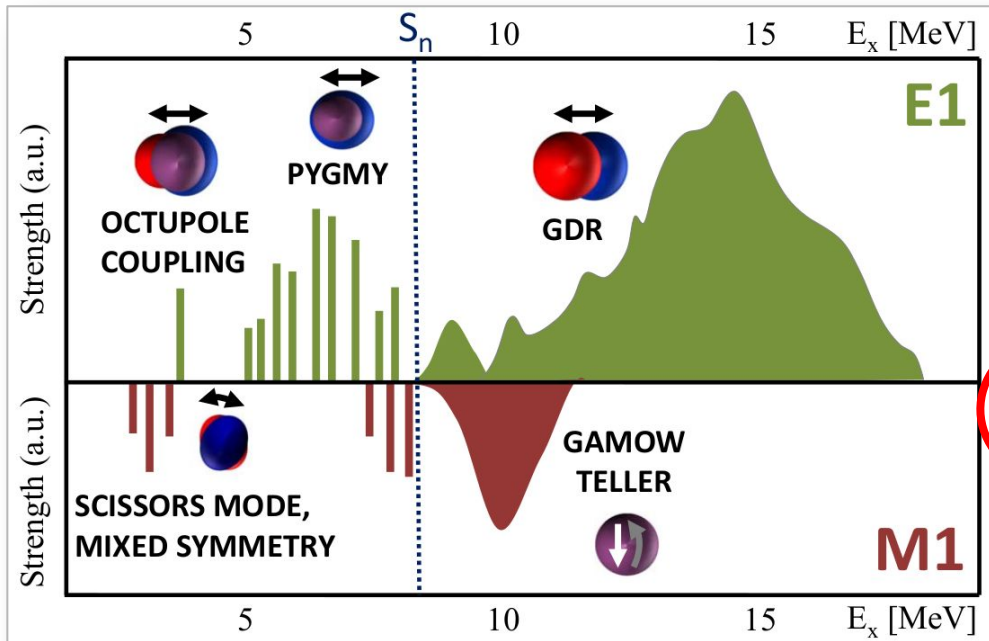
few % only of E1 strength
connected to the neutron excess excitations
resonant states present around S_n
mixed iso-scalar and iso-vector nature
less fragmented near closed shells



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PDR structure :

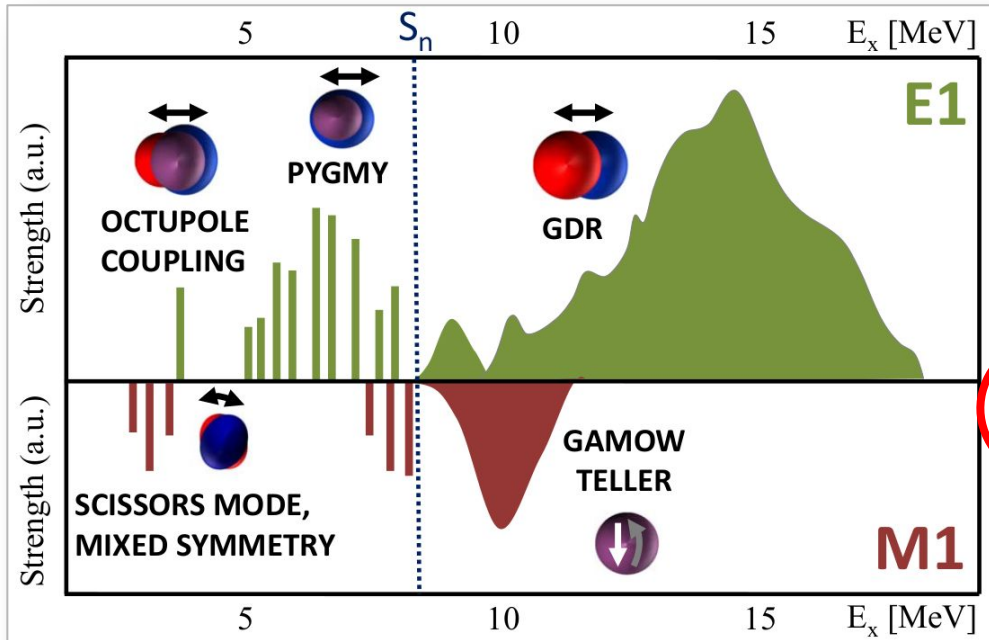
- what is the microscopic picture ?
- what is p/n contribution ?
- what is the isospin response ?
- collectif or s.p. excitations ?
- how varies with mass number ?



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Need for different
 probes
 +
 study different
 mass regions



Different probes \leftrightarrow different facets of the nucleus

Scattering of \rightarrow	real γ	hadrons
Interaction	EM	strong(+EM)
Probing :	volume	surface
Probe isospin :	IV	IS / IV
EL, ML :	E1, M1, (E2)	E0, E1, E2, E3, ...

+

coincident detection of the (γ) decay to enhance the selectivity of the L = 1 mode

Hadrons :

- α and ^{17}O \rightarrow charged, IS probes, A-body
- protons \rightarrow charged, IS + IV probes, one-body
- neutrons \rightarrow neutral, IS + IV probes, one-body !



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PDR structure probed with neutrons

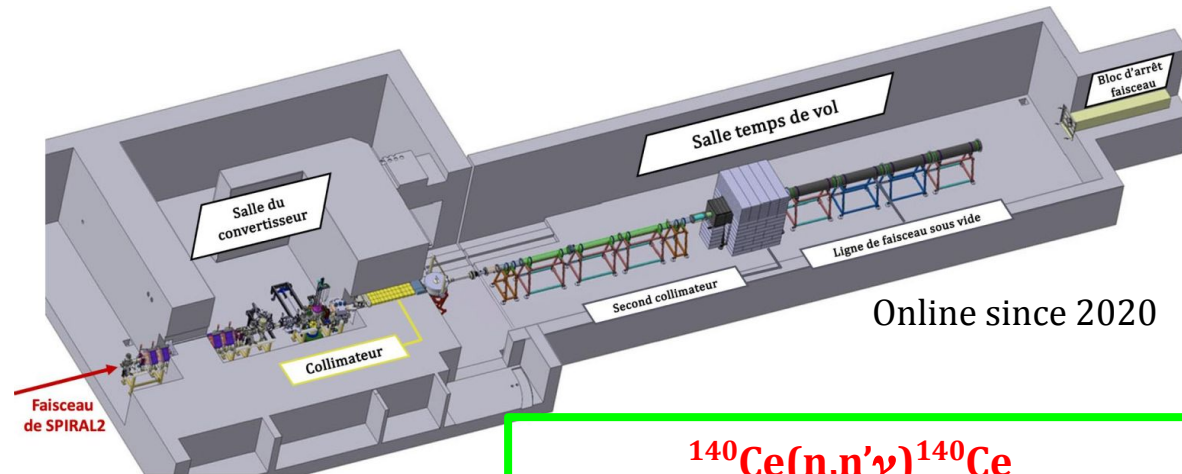
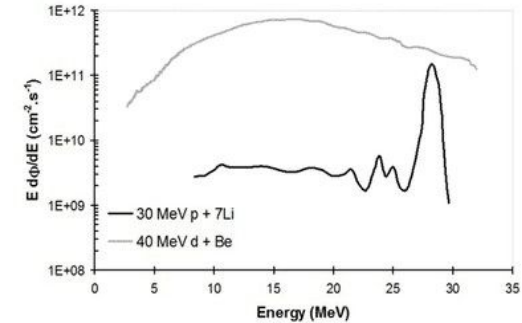
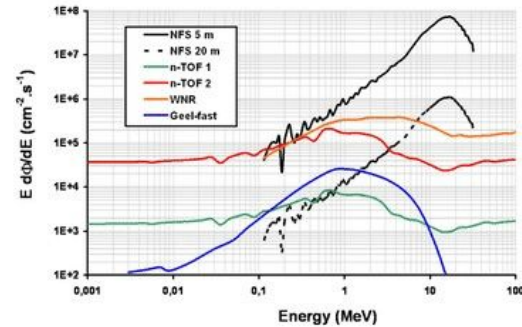
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Monoenergetic neutron beams @ NFS/GANIL

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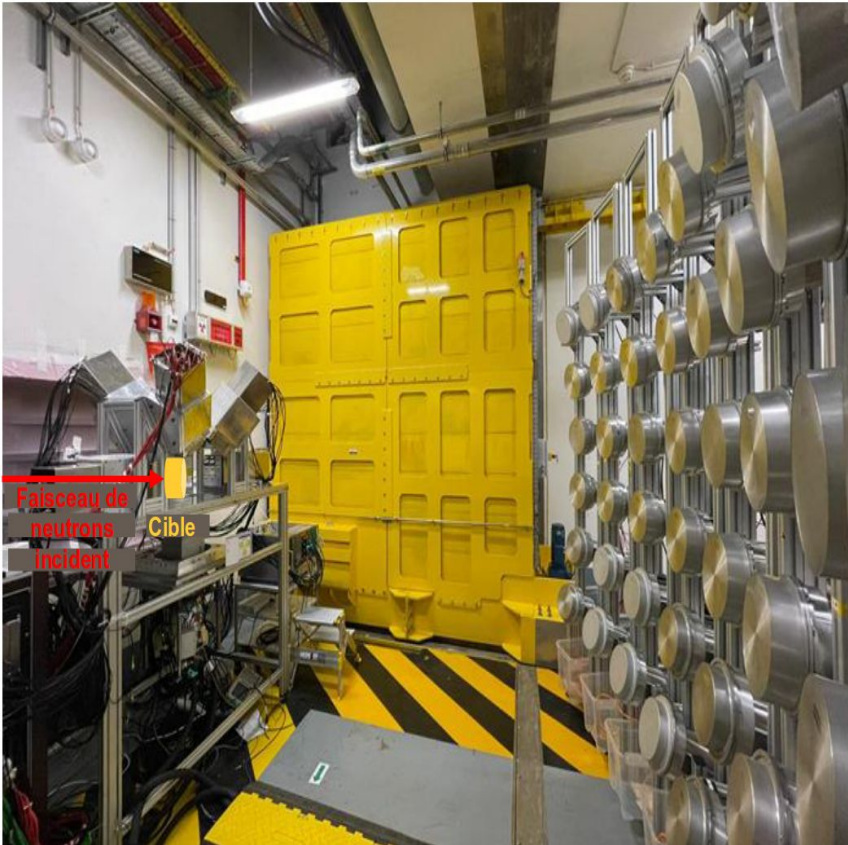
Online since 2020

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**$^{140}\text{Ce}(n,n'\gamma)^{140}\text{Ce}$
First PDR study using neutrons**

PDR in ^{140}Ce (N=82): E833 results (2022)



Beam : $E_n = 30.8$ MeV & $I_n = 2.76 \times 10^{10}$ n/sec/sr

Target : natCe @ 5m from converter

PARIS array for γ detection

- ❑ 8 clusters @ 23cm
- ❑ 2% total ph. eff. @ 8MeV
- ❑ ang. coverage: $\sim 45^\circ - \sim 165^\circ$

MONSTER array for neutron det.

- ❑ 48 cells @ 3m - 1.4% of 4π
- ❑ 12% intrinsic efficiency @ 20MeV
- ❑ ang. coverage: $\sim 5^\circ - \sim 40^\circ$

PDR in ^{140}Ce (N=82): E833 results (2022)

Eur. Phys. J. A _#####_
<https://doi.org/10.1140/epja/s10050-026-01890-9>

THE EUROPEAN
 PHYSICAL JOURNAL A

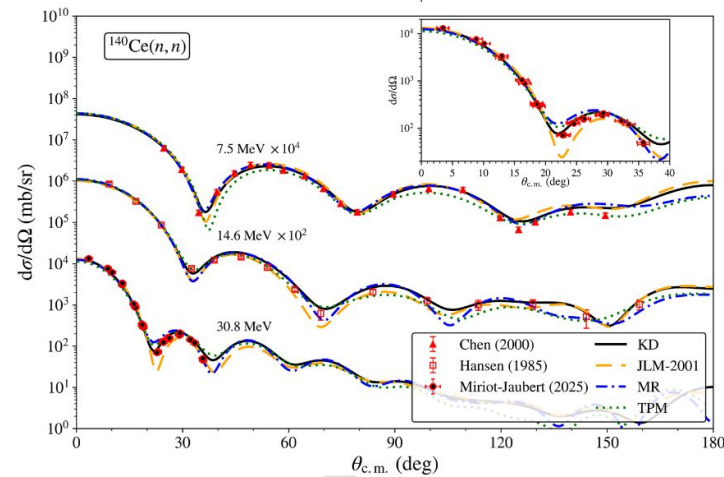


Regular Article - Experimental Physics

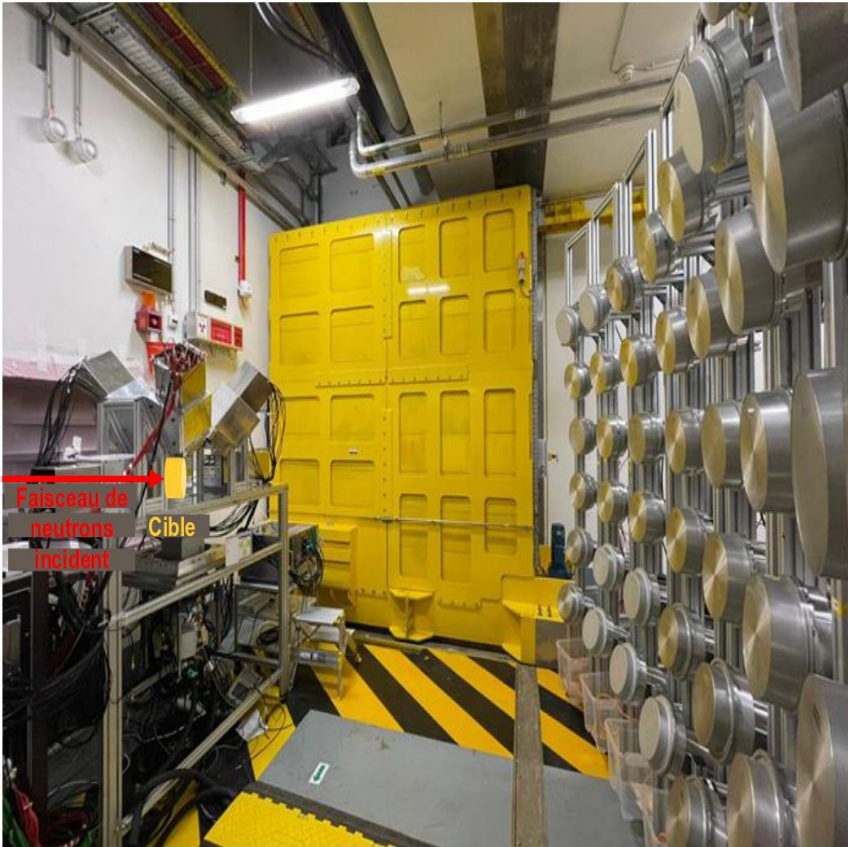
$^{140}\text{Ce}(n,n)^{140}\text{Ce}$ @ 30MeV

Neutron elastic scattering at 30.8 MeV on ^{nat}Ce

P. Miritot-Jaubert^{1,3,1,a}, M. Vandebrouck¹, I. Matea², D. Doré¹, M. Dupuis³, X. Ledoux⁴, T. Martinez⁵, A. Pérez de Rada Fiol⁵, S. Péru³, N. L. Achouri⁶, L. Al Ayoubi⁶, D. Beaumel⁷, Y. Blumenfeld², S. Calinescu⁷, D. Cano Ott⁵, M. Ciemala⁸, A. Corsi¹, F. Crespi⁹, Y. Demane¹⁰, W. Dong², O. Dorvaux¹¹, J. Dudouet¹⁰, D. Etasse⁶, A. M. Frelin⁴, J. Gibelin⁶, M. N. Harakeh¹², M. Kmiecik⁸, M. Lebois², M. Lewitowicz¹³, A. Maj⁸, J. Plaza del Olmo⁵, D. Ramos⁴, E. Rey-herme¹, Ch. Schmitt¹¹, M. Stanoiu⁷, O. Stezowski¹⁰, Ch. Theisen¹, D. Thisse¹, L. Thulliez¹, G. Tocabens², D. Villamarin⁵, M. Zielińska¹



- (by-product)
- first measurement above 20MeV
- good comparison with theoretical predictions and evaluations
- **article in press**



Beam : $E_n = 30.8$ MeV & $I_n = 2.76 \times 10^{10}$ n/sec/sr

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PARIS array for γ detection

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- | | |
|--|--|
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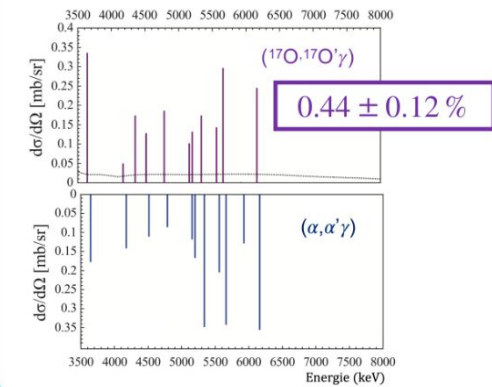
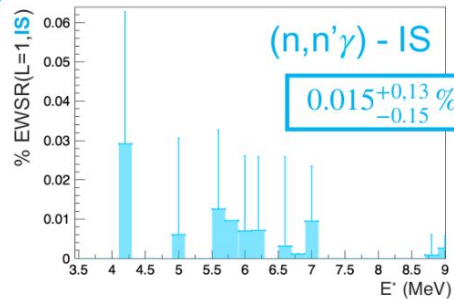
PDR in ^{140}Ce (N=82): E833 results (2022)

First decomposition analysis in terms of isospin response (IV vs IS) using a single probe

$^{140}\text{Ce}(n,n'\gamma)^{140}\text{Ce}$ @
30 MeV

article in preparation

Isoscalar (IS) probes

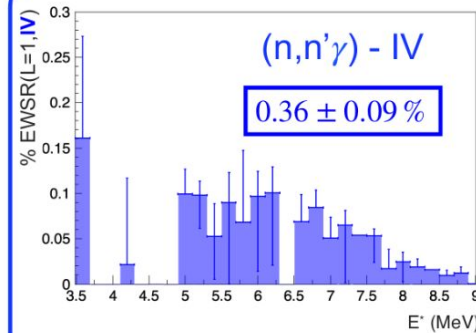


Isoscalar states populated up to 6,2 ou 7 MeV

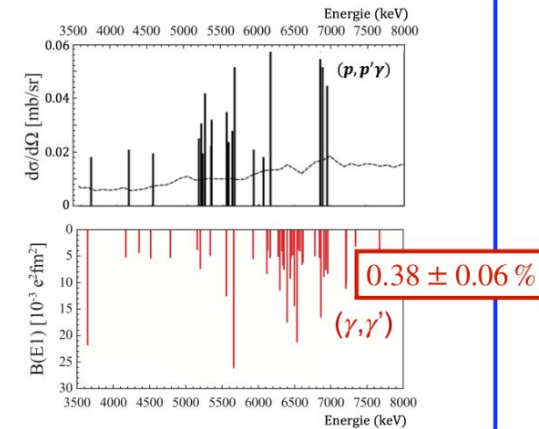
✓ No IS states in the high energy region

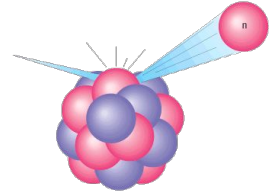
(Courtesy of P. Miriot-Jaubert)

Isovector (IV) and mixed (IS+IV) probes



✓ States populated in the whole energy region





Conclusions

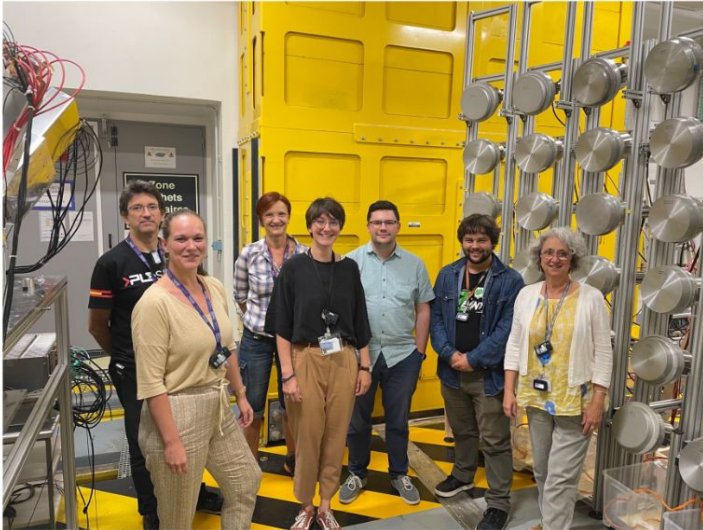
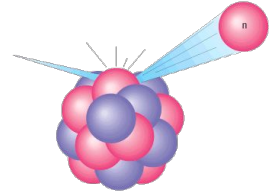
- ❑ First measurement of the PDR via neutron inelastic scattering : Study in ^{140}Ce at NFS/GANIL-SPIRAL2
- ❑ Extraction of the dipole strength from scattered neutrons angular distribution and QRPA + DWBA predictions
- ❑ Results compatible with previous multi-messenger investigations of the PDR in ^{140}Ce
- ❑ Few % of the EWSR exhausted
- ❑ First decomposition analysis in terms of isospin response (IV vs IS) using a single probe → article in preparation

Perspectives

- ❑ use complementarity of **n** and **p** probes to extract informations on the structure of PDR
- ❑ comparison against different microscopic predictions : QRPA, QPM, SRPA ...
- ❑ program continued at NFS with $^{88}\text{Sr}(n,n'\gamma)^{88}\text{Sr}$ - Spring 2027



Thank you for your attention!



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