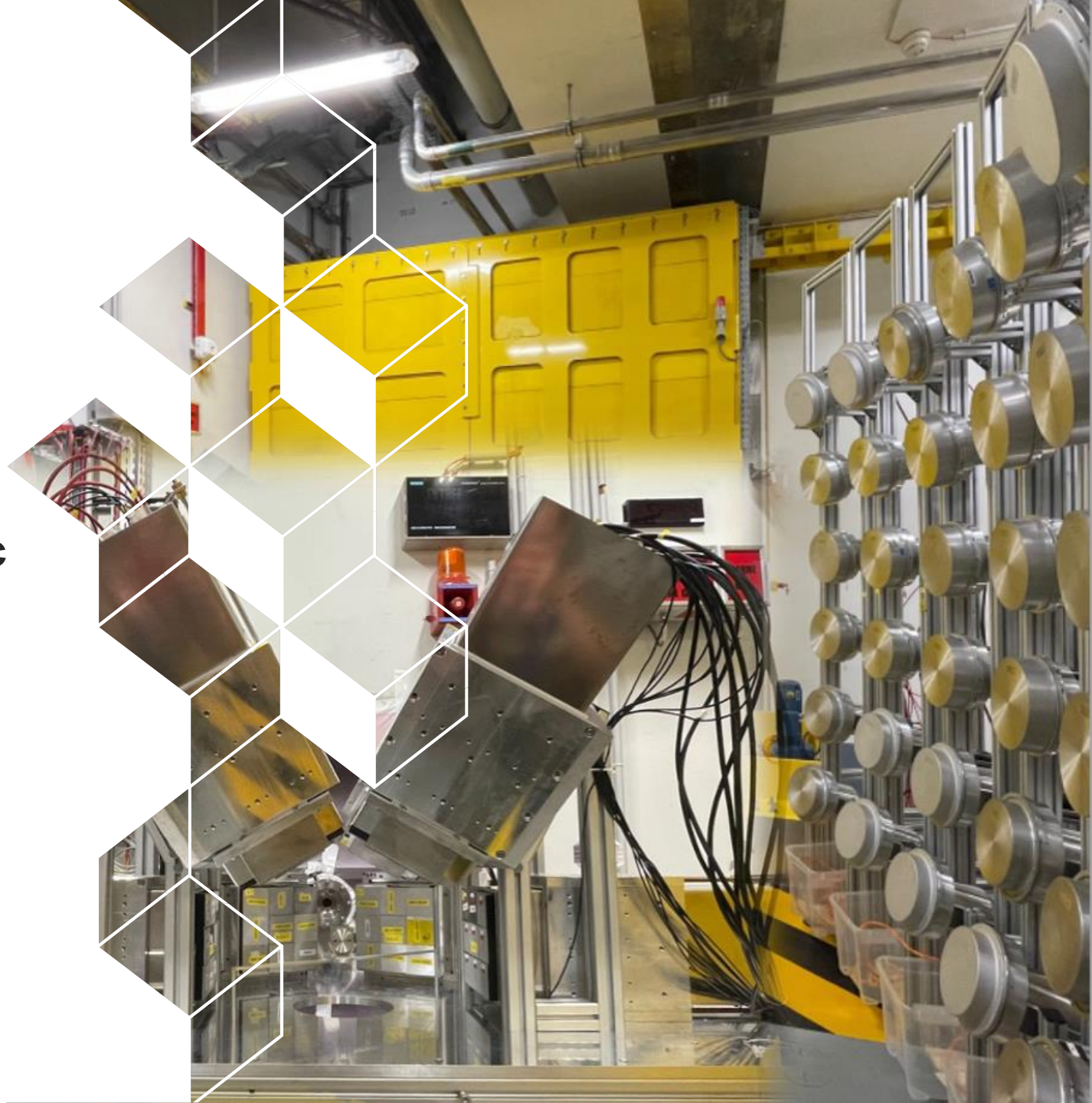
cea irfu

First nuclear structure measurement at GANIL-SPIRAL2/NFS :

The study of the Pygmy Dipole Resonance via neutron inelastic scattering

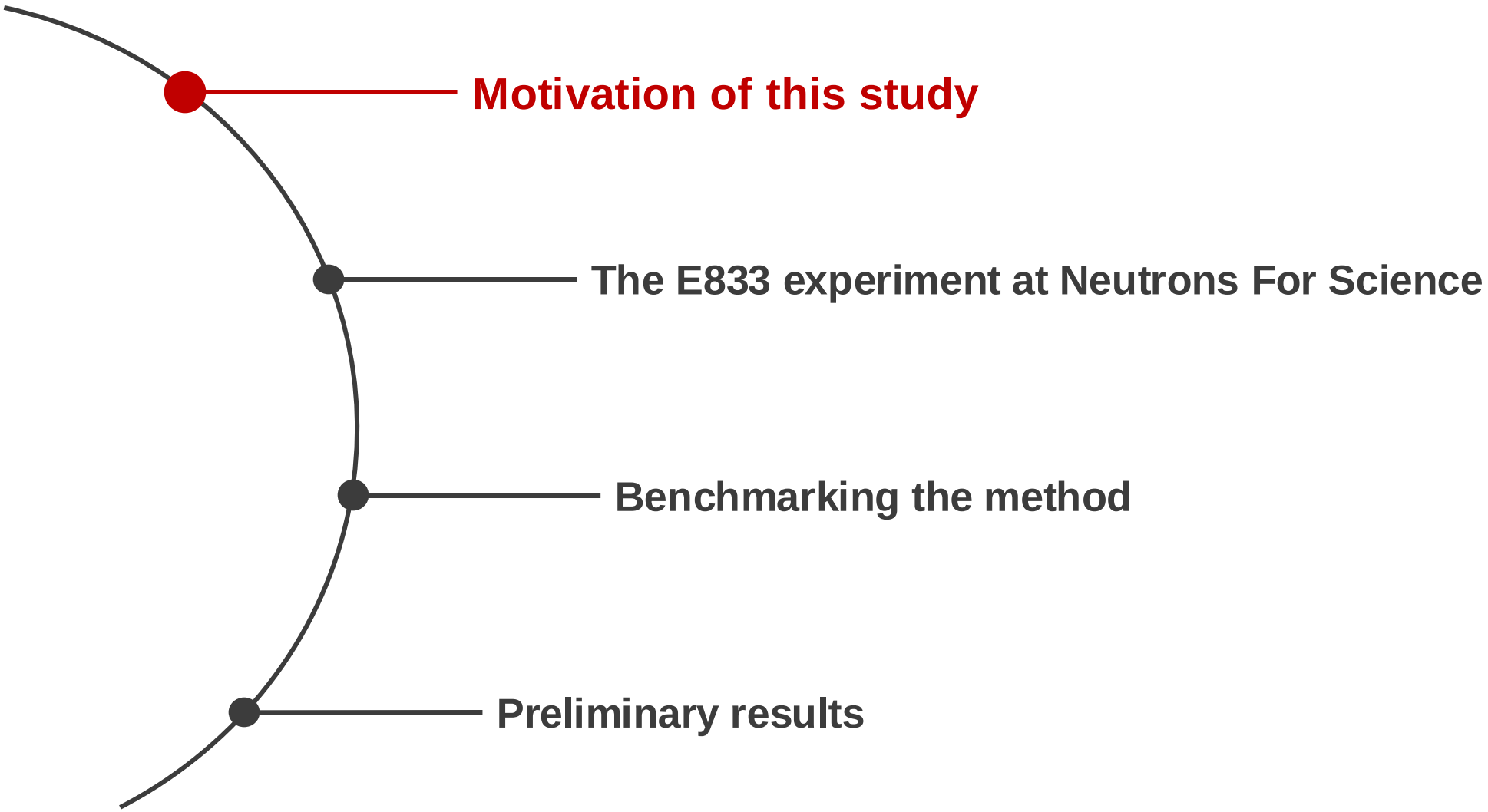


Périne MIRIOT-JAUBERT – 3^{rd} year PhD student

Thesis director : Marine VANDEBROUCK

PARIS and MONSTER collaborations

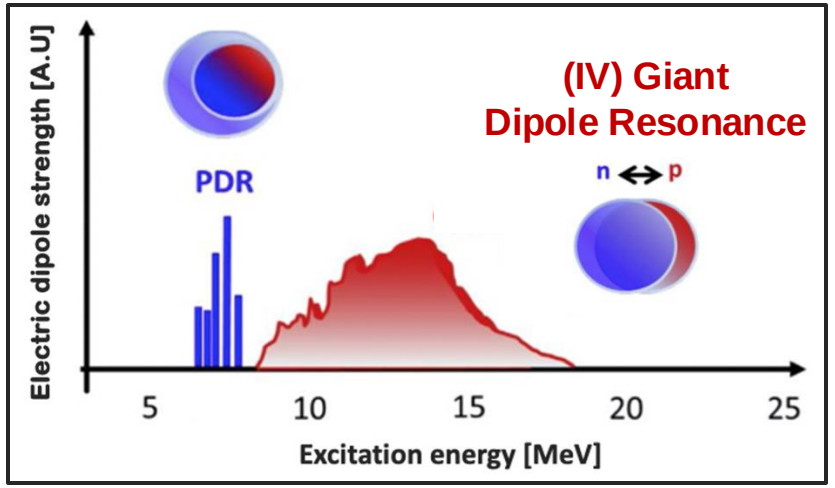
Outline - The study of the PDR @ GANIL-SPIRAL2/NFS



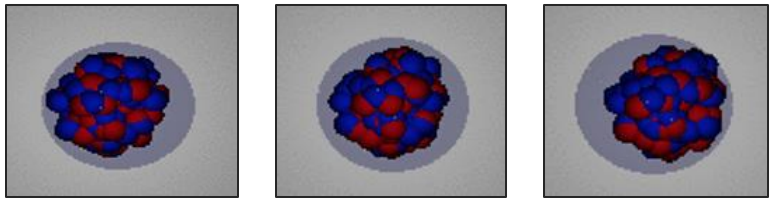
The Pygmy Dipole Resonance (PDR)

1) An exotic excitation mode of dipole nature …

- **Low energy electric dipole** strength
- Characteristic of **neutron-rich nuclei**
- Around the neutron separation energy threshold



*A. Bracco, E.G. Lanza and A. Tamii, Phys. Rev. B **106**, 360-433 (2019)*



2) … often described macroscopically as:

The oscillation of a **neutron skin** around an **isospin symetric core**

3) … with possible interest in:

▷ Astrophysical r-process

▷ Nuclear equation of state (neutron stars properties)

The Pygmy Dipole Resonance (PDR)

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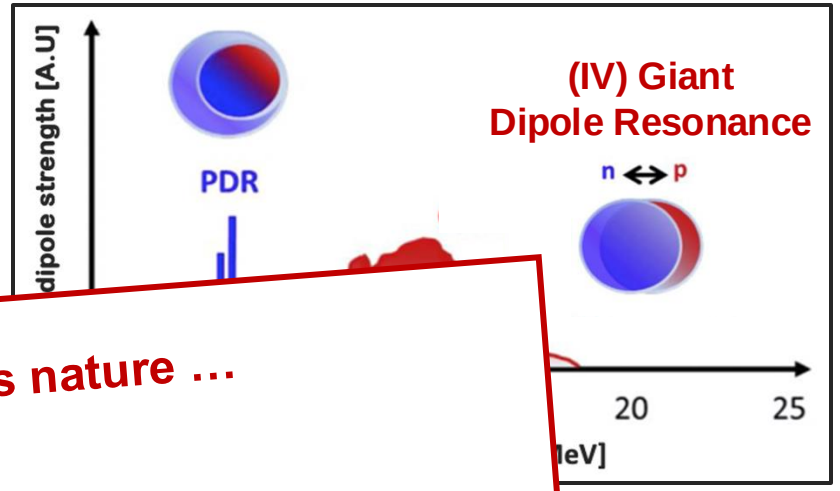


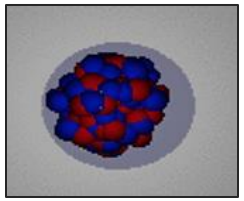
*. B **106**, 360-433 (2019)*

But still unresolved questions on its nature …

? *Collectivity*

? ***Isospin nature***

? *Evolution towards the dripline*

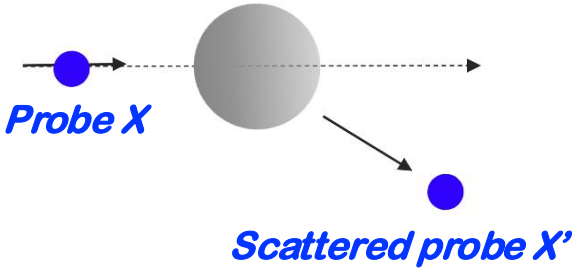


…illation of a **neutron skin** around an **isospin symetric core**

3) … with possible interest in:

▷ Astrophysical r-process ▷ Nuclear equation of state (neutron stars properties)

The interest of scattering experiments

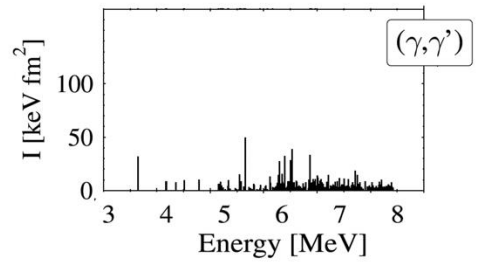


Different probes will not have the same **ability to excite protons and neutrons**

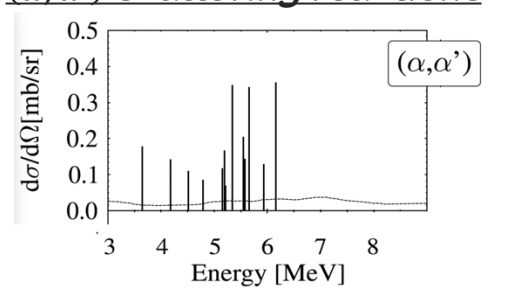
→ Interest of a **« multi-messenger » investigation** of the PDR

*D. Savran et al., Physics Letters B **786** (2018) 16-20*
Multi-messenger investigation of the Pygmy Dipole Resonance in ^{140}Ce

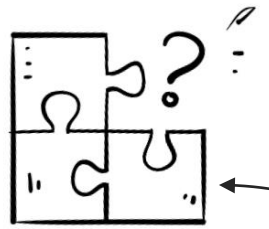
(γ,γ') scattering reactions



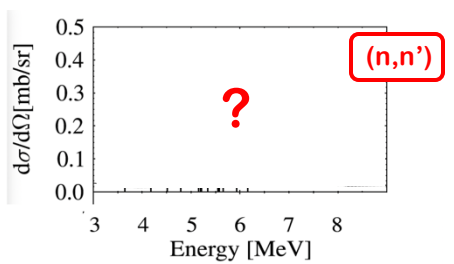
(α,α') scattering reactions



Nature of the PDR



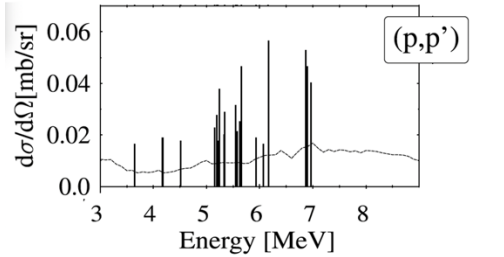
This work: (n,n') scattering reaction



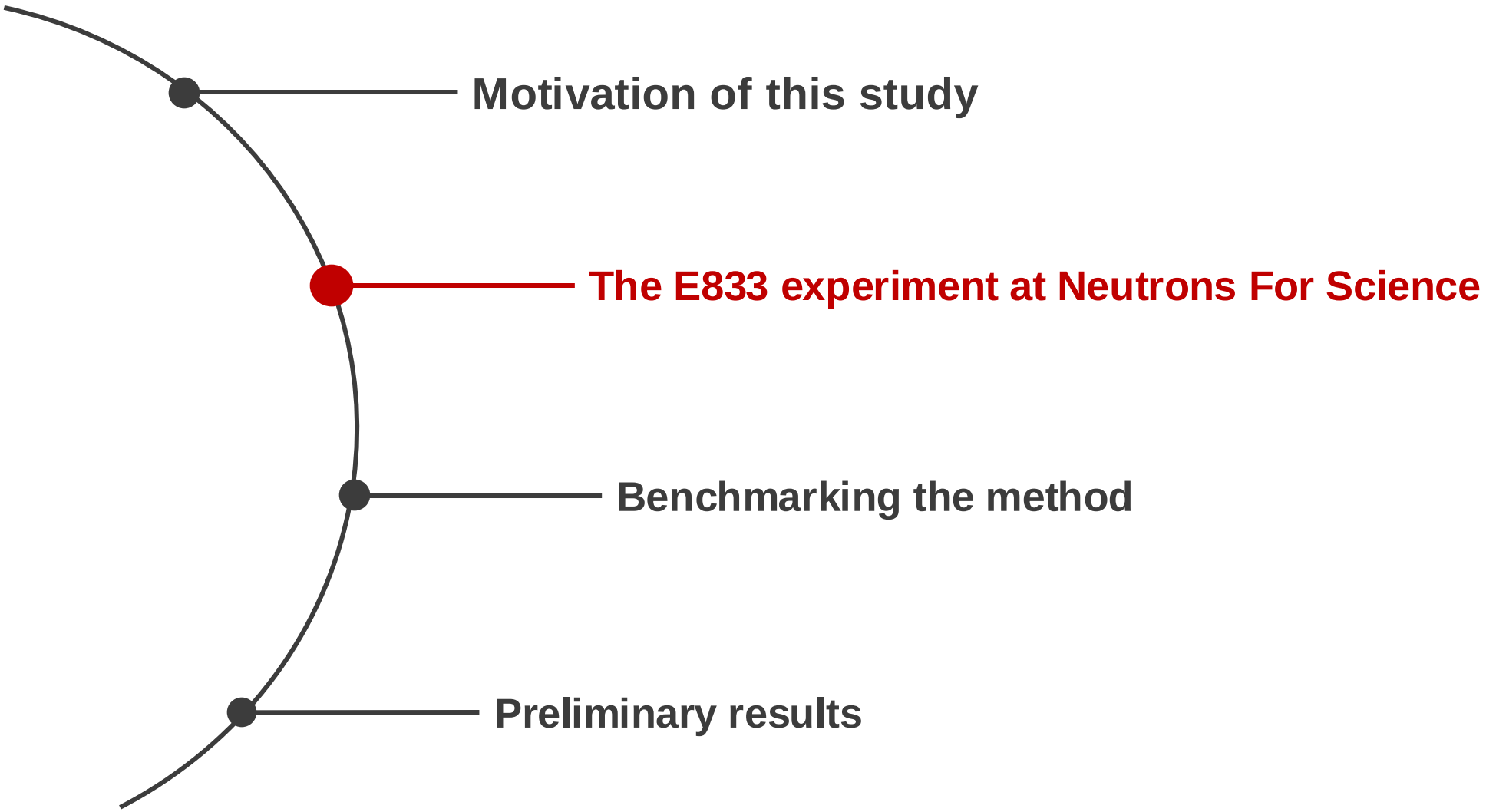
Advantages :

- *elementary probe in nuclear physics*
- *electrically neutral*
- *complementary to (p,p')*

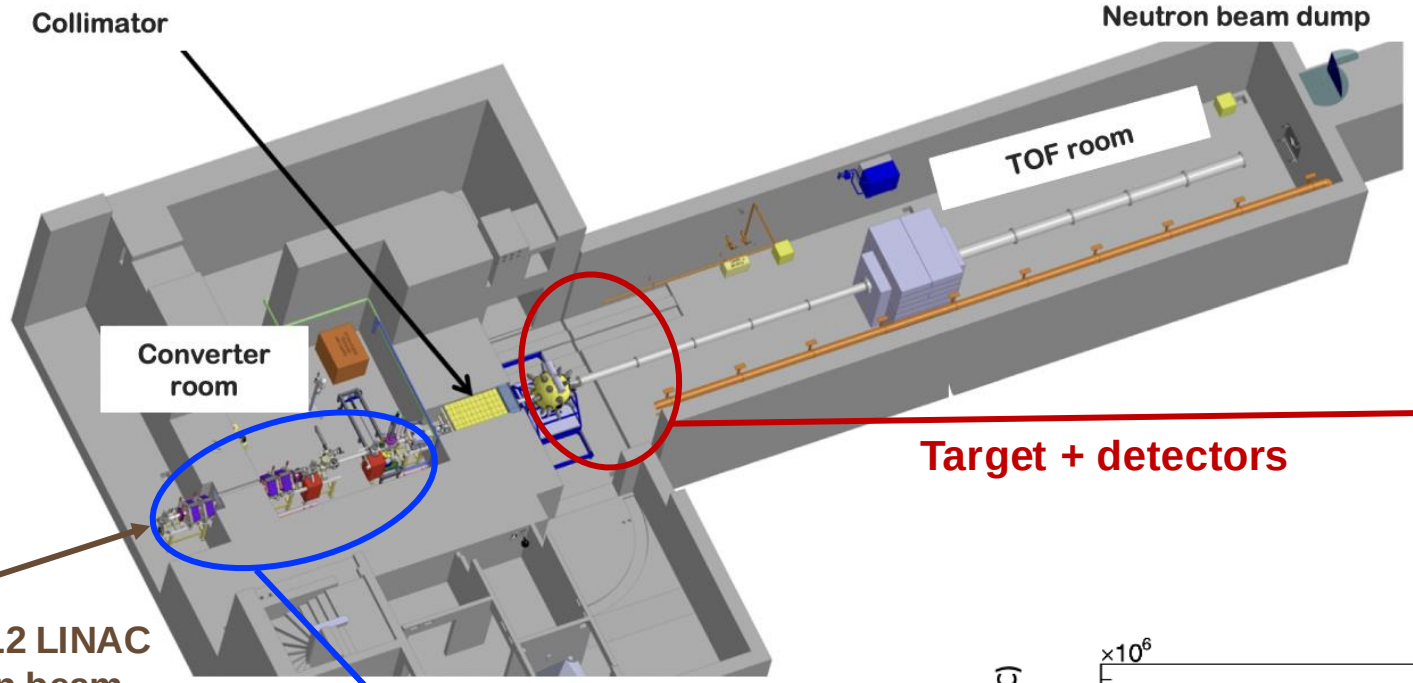
(p,p') scattering reactions



Outline - The study of the PDR @ GANIL-SPIRAL2/NFS



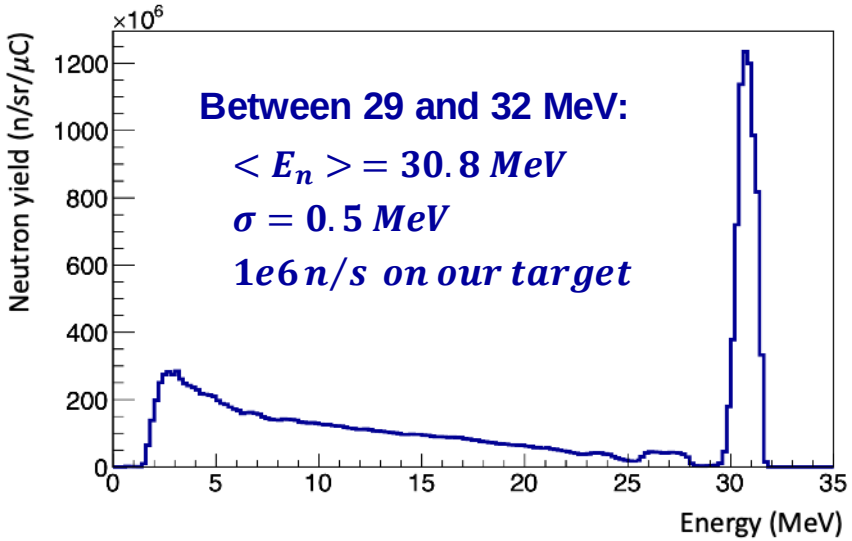
GANIL–SPIRAL2/NFS experimental area : a new opportunity



SPIRAL2 LINAC
Proton beam
(33 MeV – 20 uA)

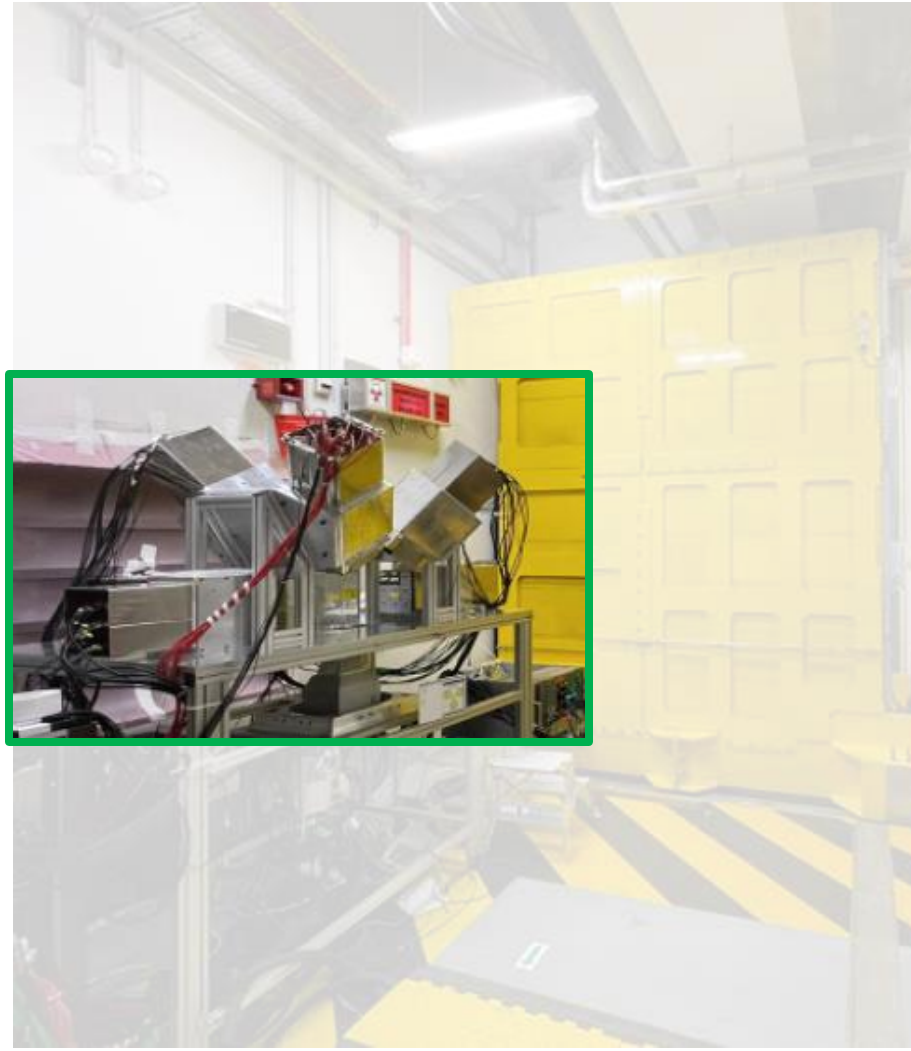
Generation of the neutron beam via the charge exchange reaction :
$^{7}Li(p,n)^{7}Be$

Target + detectors



X. Ledoux et al., Eur. Phys. J. A, 57;257 (2021).

The experimental setup – E833 experiment (Sept. 2022)



Study of the PDR in the ^{140}Ce (~ 88% in ^{nat}Ce) :

^{nat}Ce(n,n')^{nat}Ce*(γ)^{nat}Ce

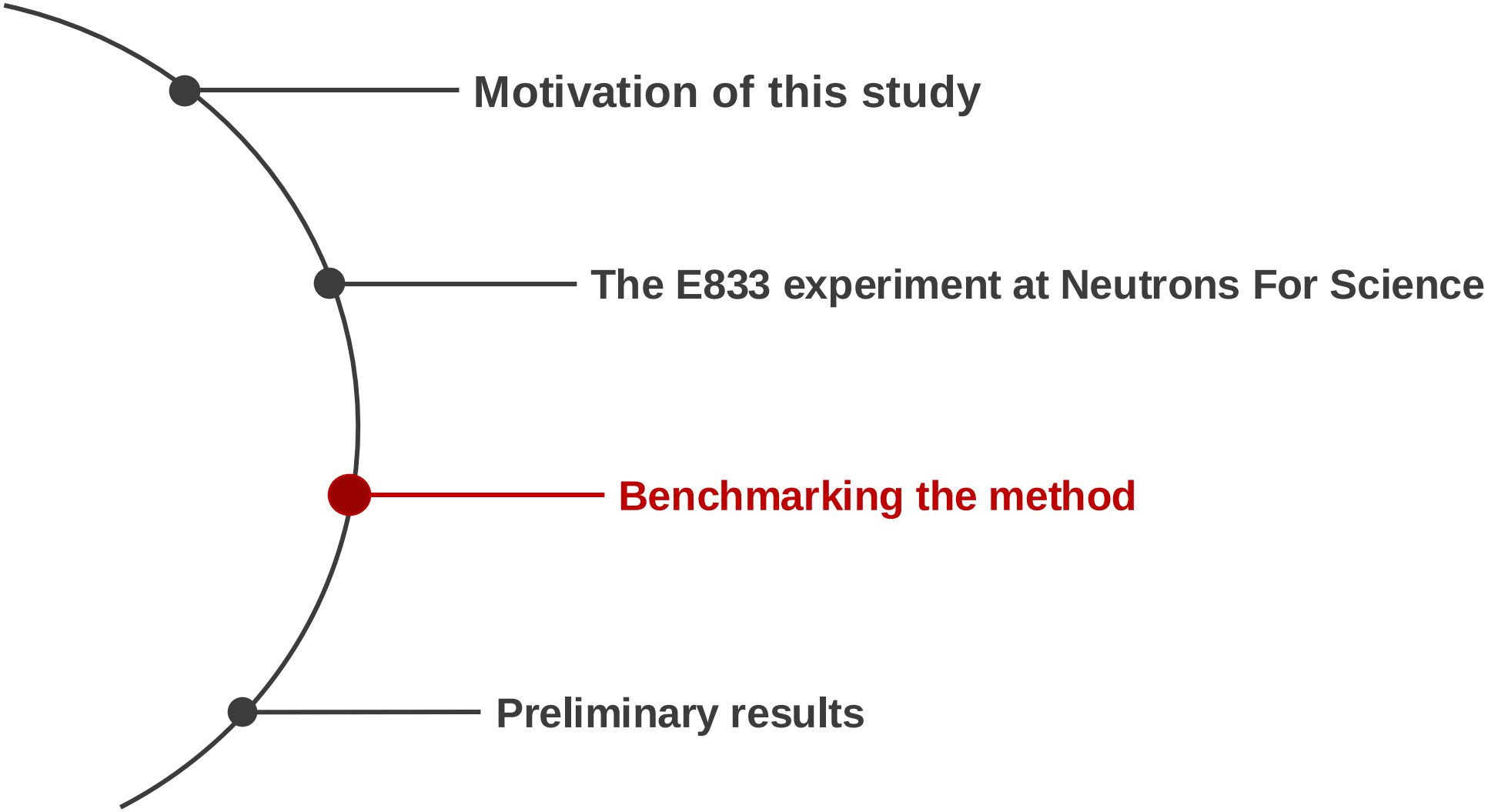
MONSTER modules (x 48) : n' detection

Liquid scintillators (BC501A / EJ301)

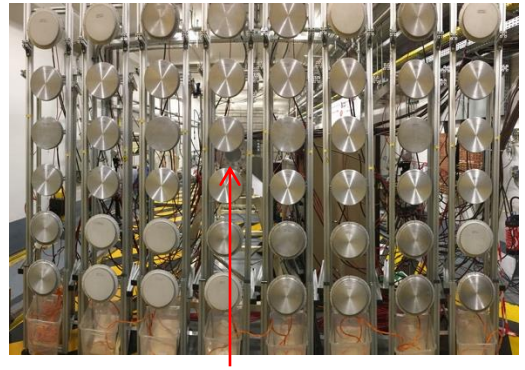
PARIS clusters (x 8) : γ detection

Scintillation crystals (LaBr / CeBr + NaI)
8 clusters of 9 phoswiches each

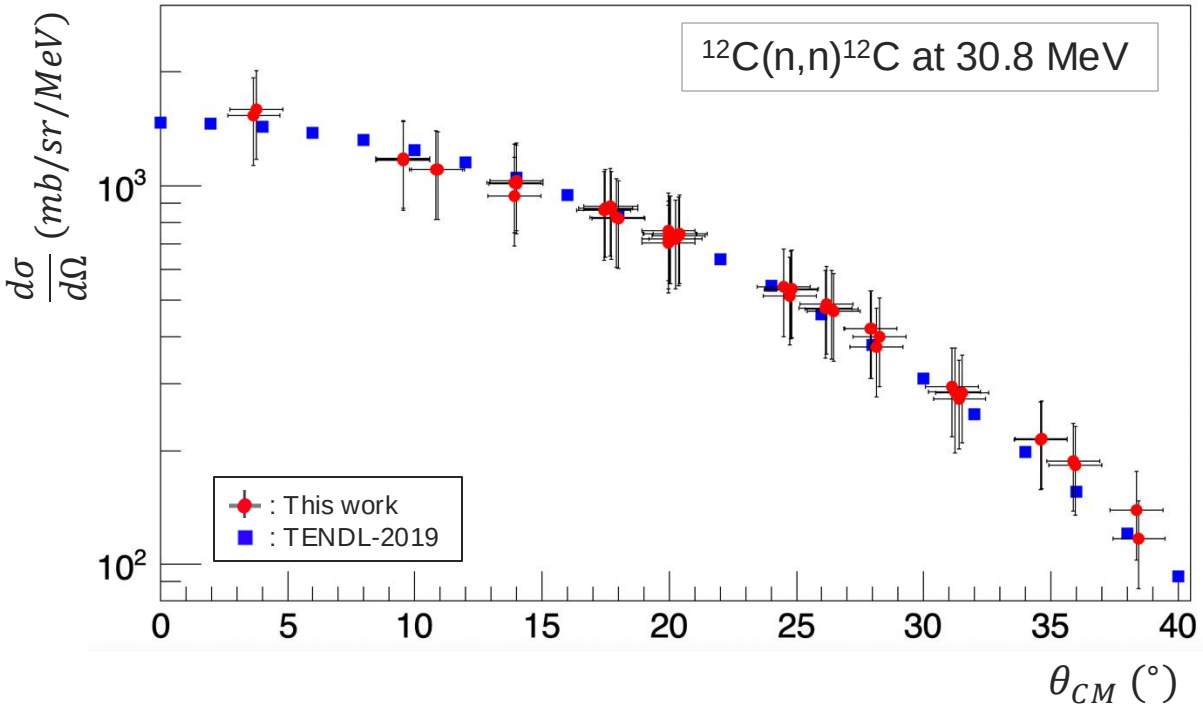
Outline - The study of the PDR @ GANIL-SPIRAL2/NFS

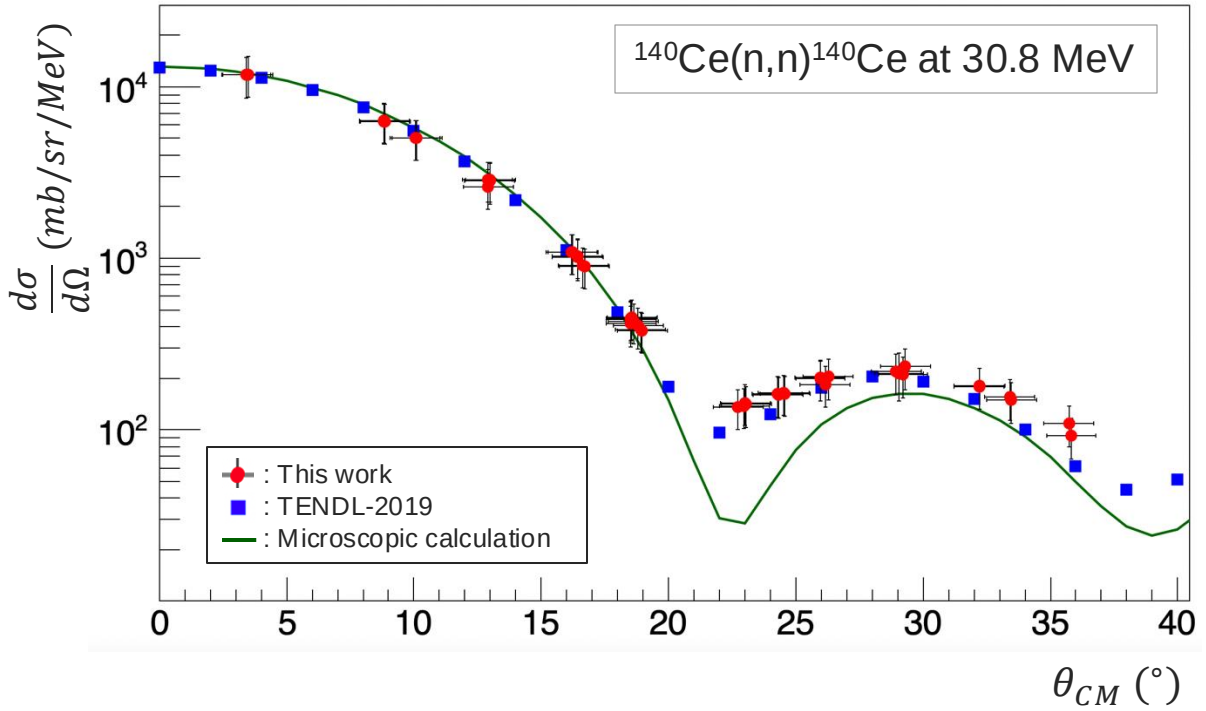


Elastic scattering analysis : $^{nat}C(n,n)^{nat}C$ and $^{nat}Ce(n,n)^{nat}Ce$



Angular differential cross-section results:



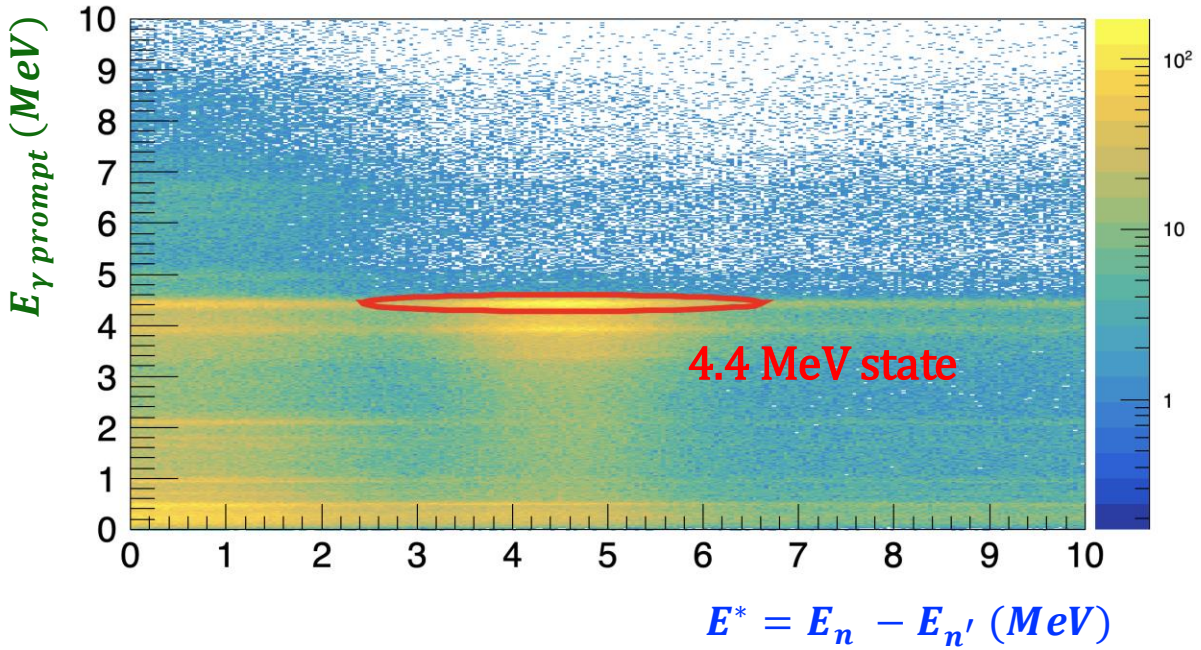


✓ Validation of the analysis method for the **reconstruction of the scattered neutron**

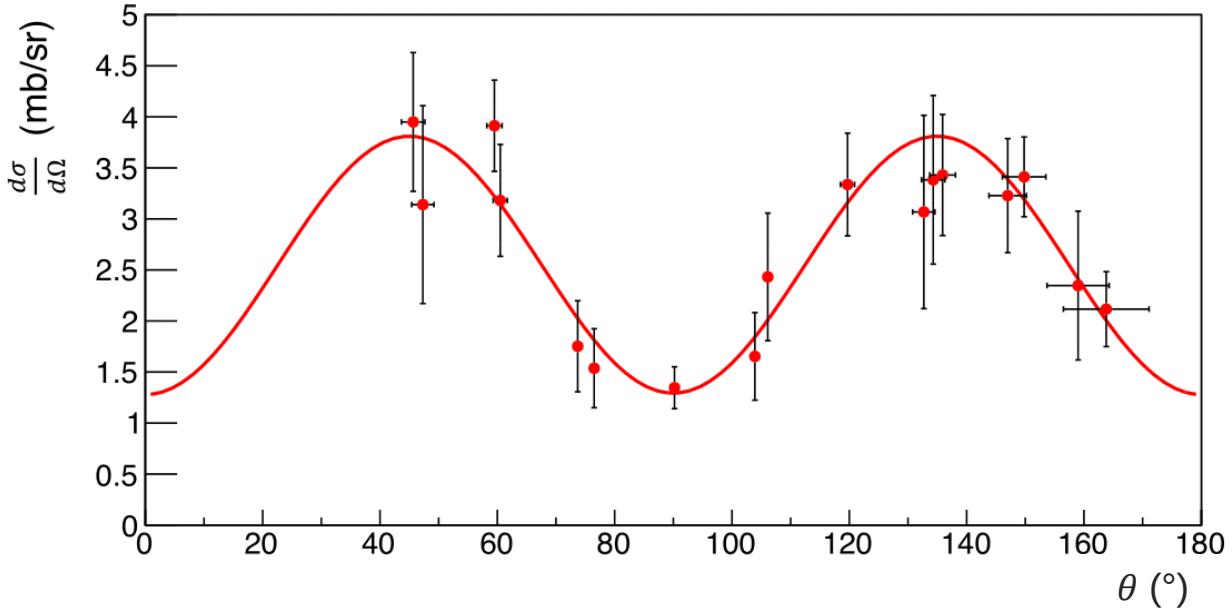
Inelastic scattering analysis : $^{nat}C(n,n')^{nat}C^{*}(\gamma)^{nat}C$

Study of the first 2^+ excited state of ^{12}C at 4.440 MeV

1) Coincidence matrix:



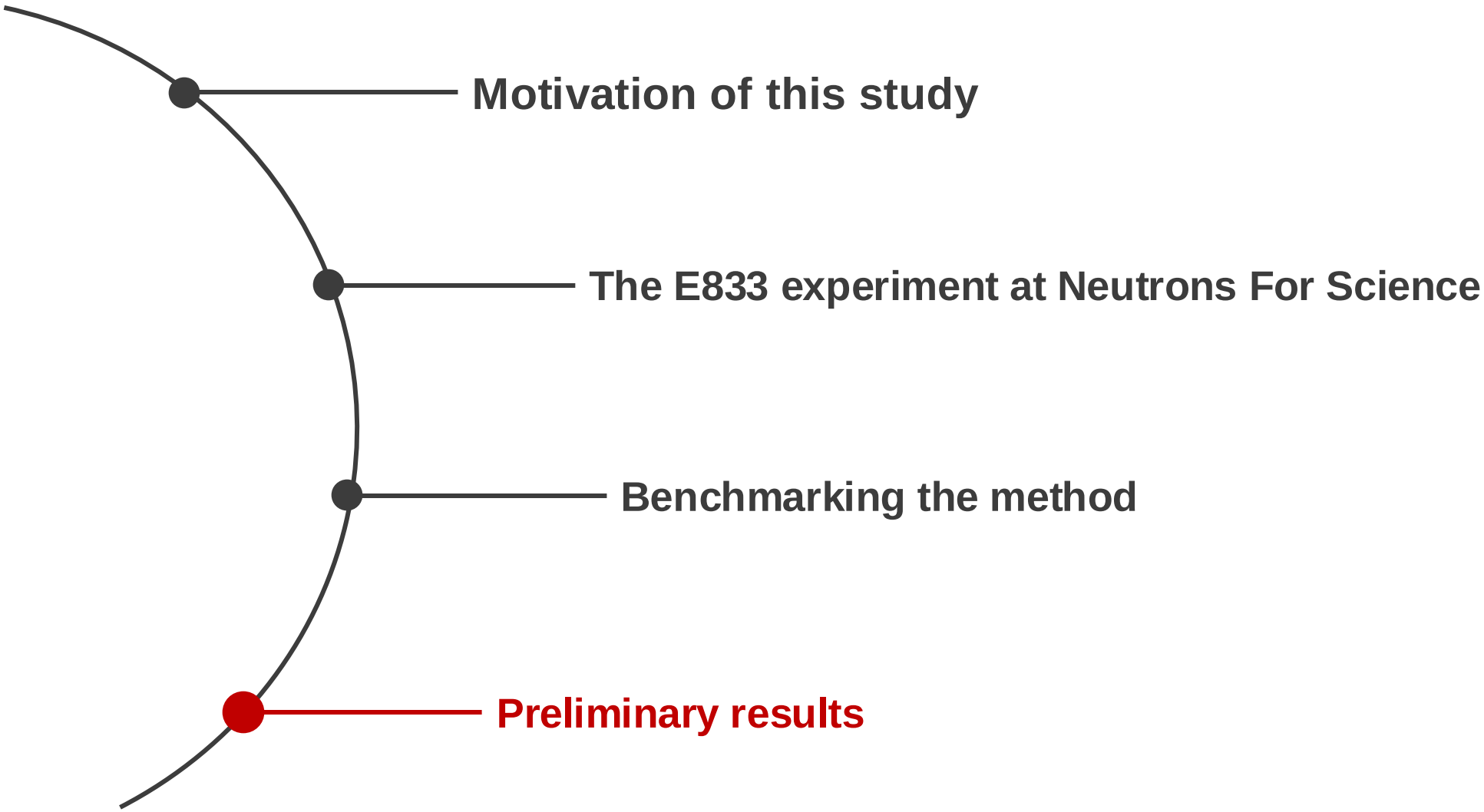
2) γ-ray angular distribution in the PARIS array:



✓ Validation of the analysis method for the **n'**- γ coincidences

✓ Signature of a quadrupole shape :
- maxima at 45 and 135°
- minimum at 90°

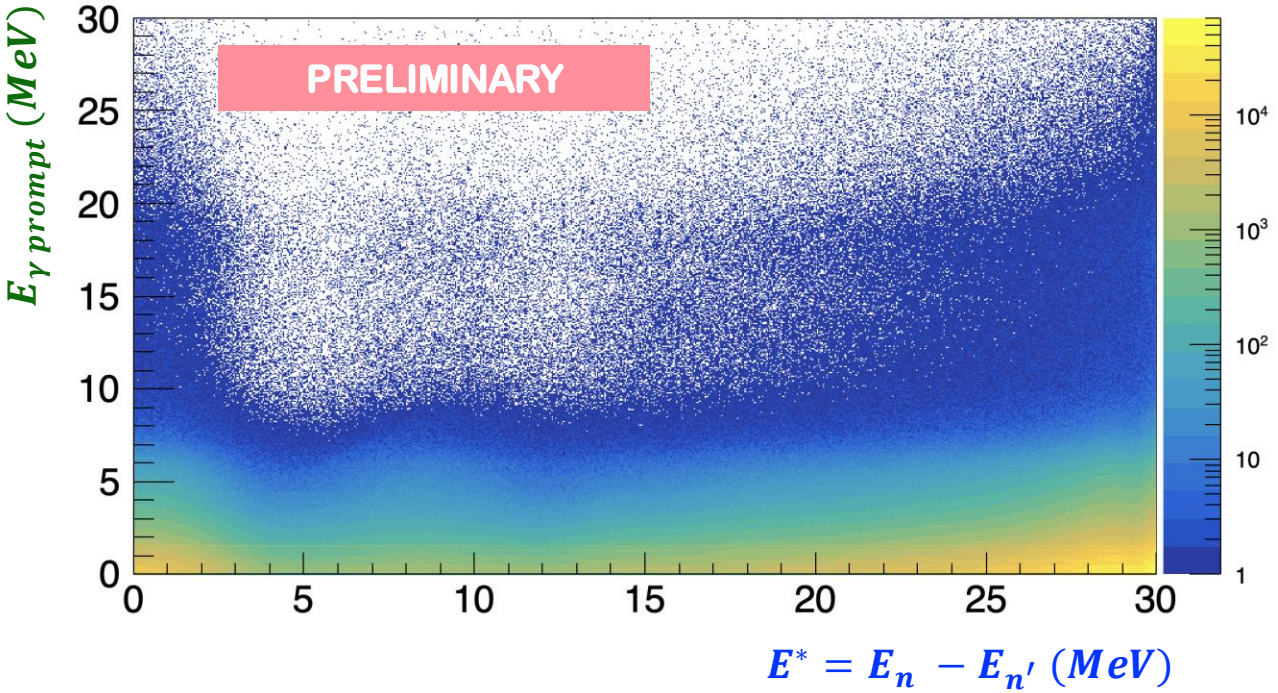
Outline - The study of the PDR @ GANIL-SPIRAL2/NFS



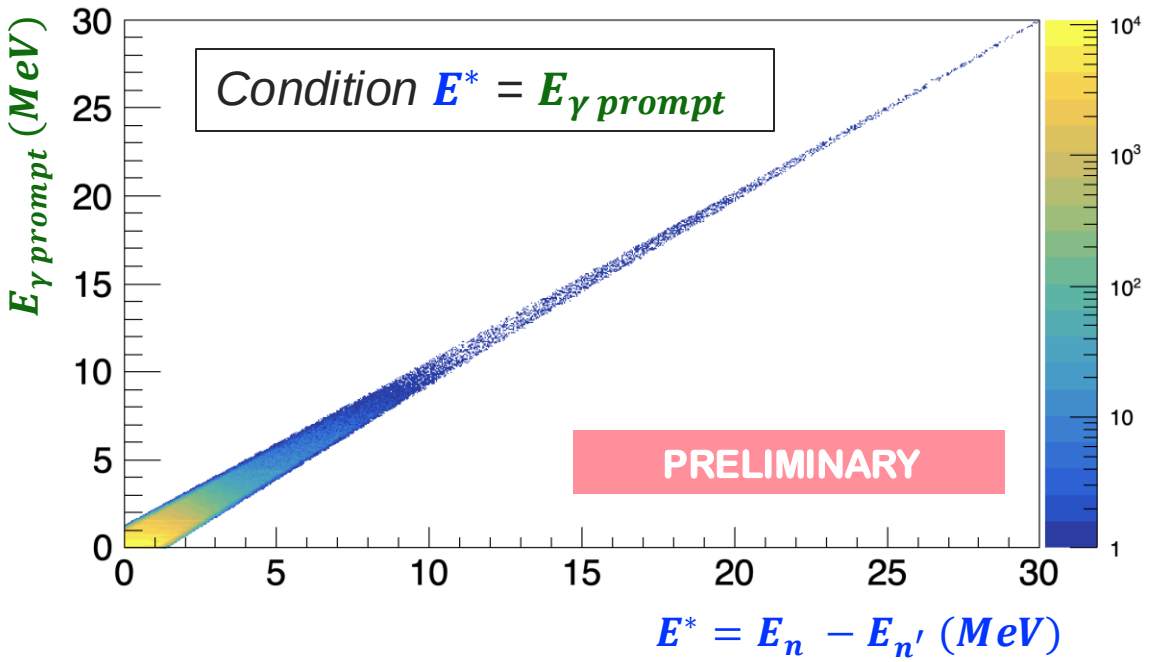
Inelastic scattering analysis : $^{nat}Ce(n,n')^{nat}Ce^{*}(\gamma)^{nat}Ce$

Study of the PDR in ^{140}Ce – Ongoing analysis, Goal: extraction of the dipole strength distribution

1) Coincidence matrix:



1') Selection of direct decays to the ground state:



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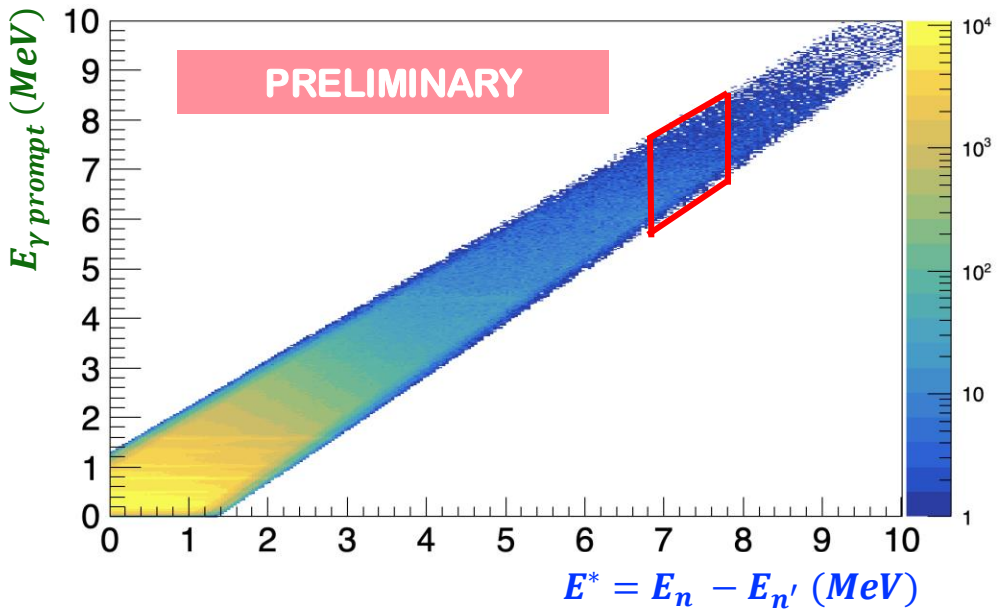
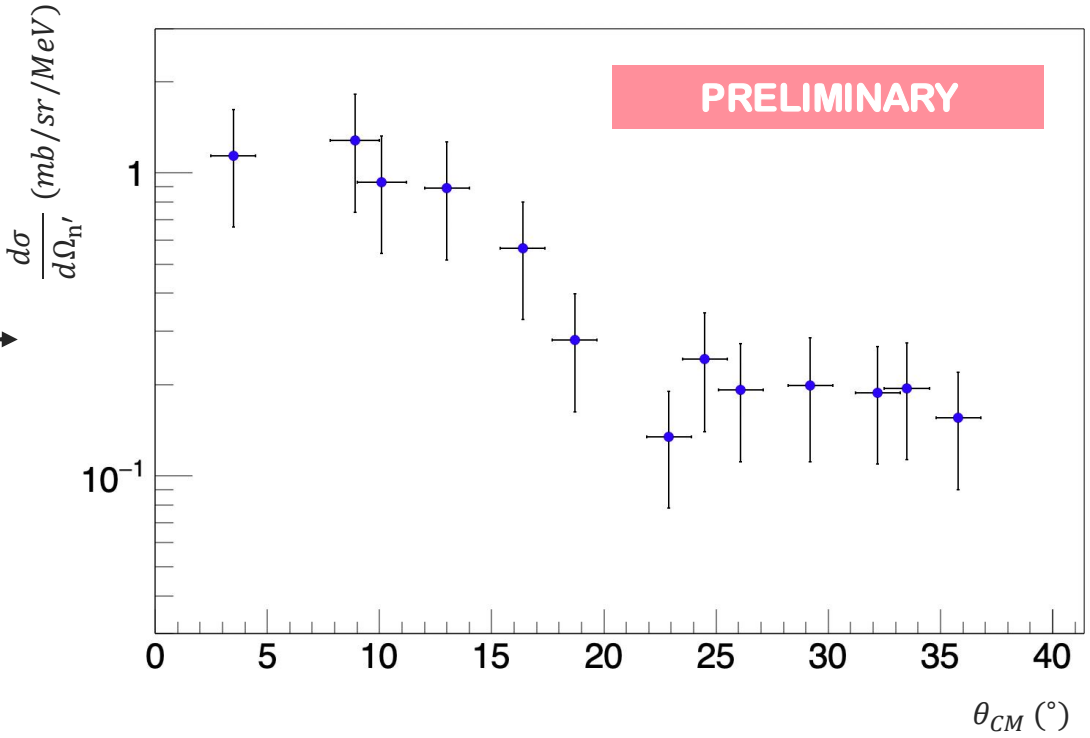
Study of the PDR in ^{140}Ce – Ongoing analysis, Goal: extraction of the dipole strength distribution

2) Scattered neutron angular distributions in MONSTER

For **slices in energy**… → … Plot the **scattered neutron angular distribution**



Example for $E^* \in [6.8, 7.8] MeV$



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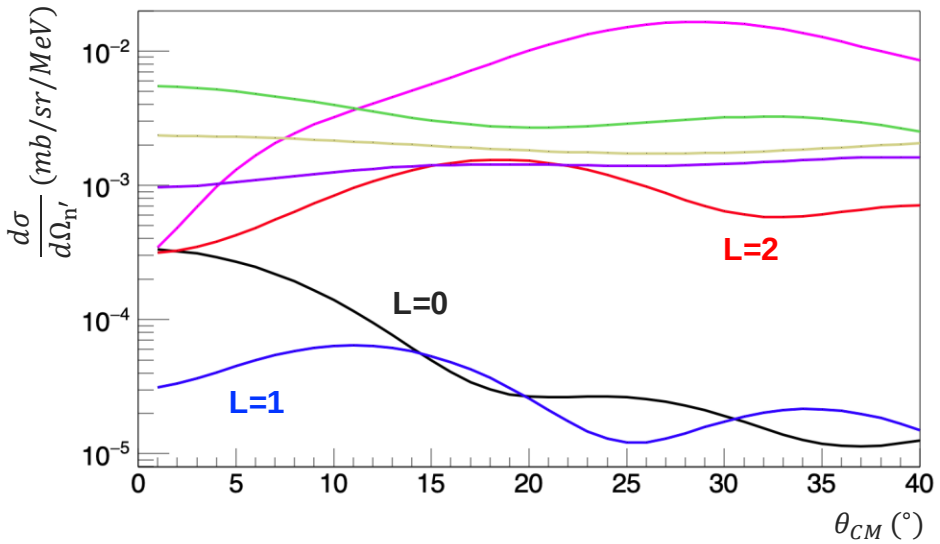
Study of the PDR in ^{140}Ce – Ongoing analysis, Goal: extraction of the dipole strength distribution

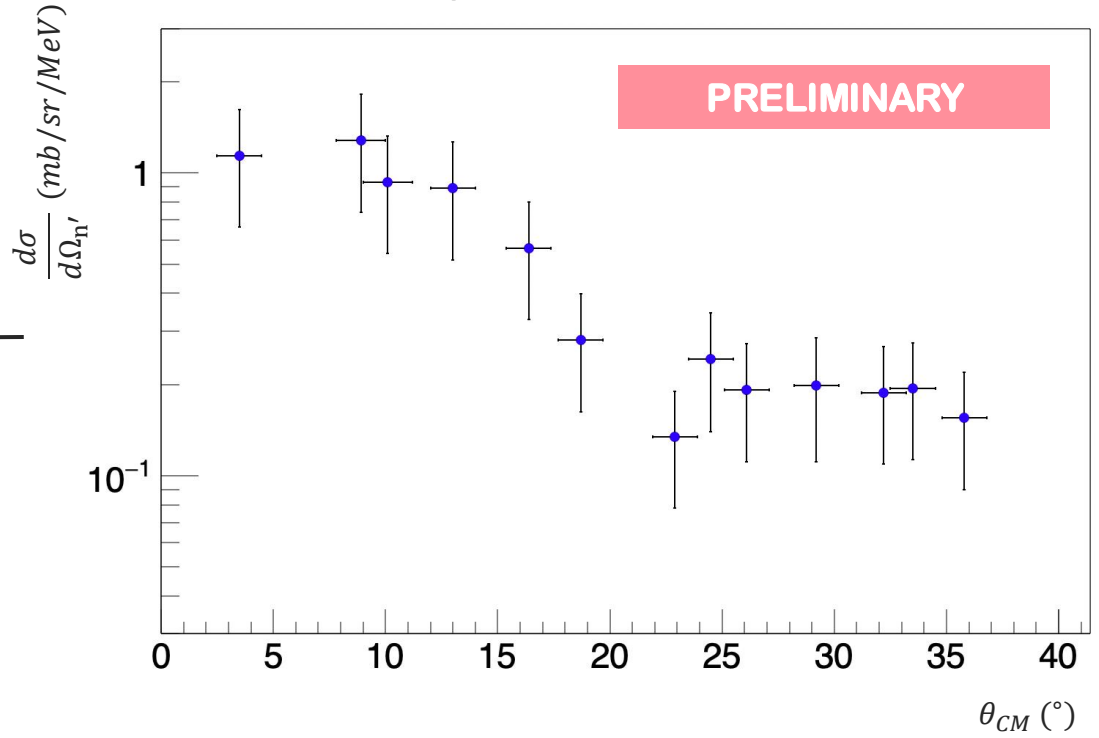
3) Extraction of the dipole strength from a Multipole Decomposition Analysis (MDA)

Theoretical predictions for $E^* \in [6.8, 7.8] MeV$



*Calculations: S. Péru (**QRPA**) and M. Dupuis (**DWBA**) from CEA, DIF*

Example for $E^* \in [6.8, 7.8] MeV$



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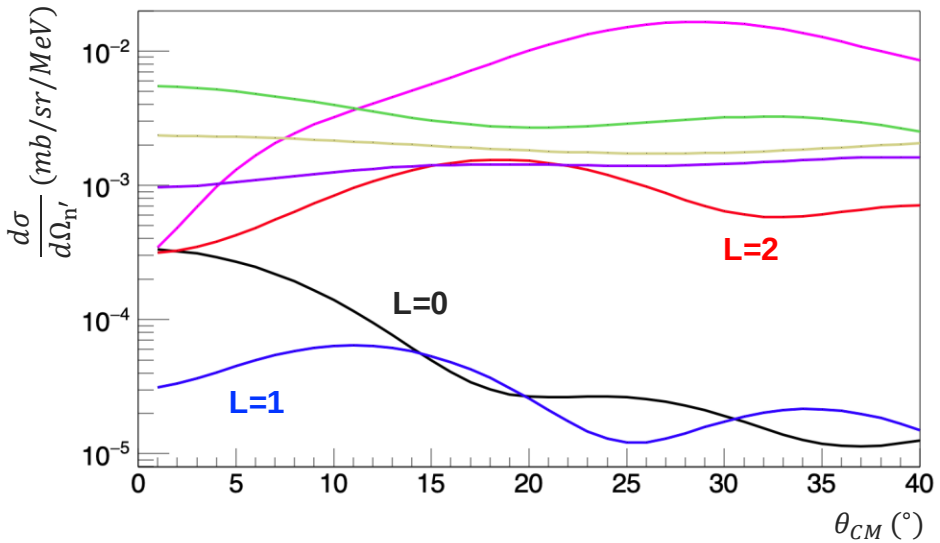

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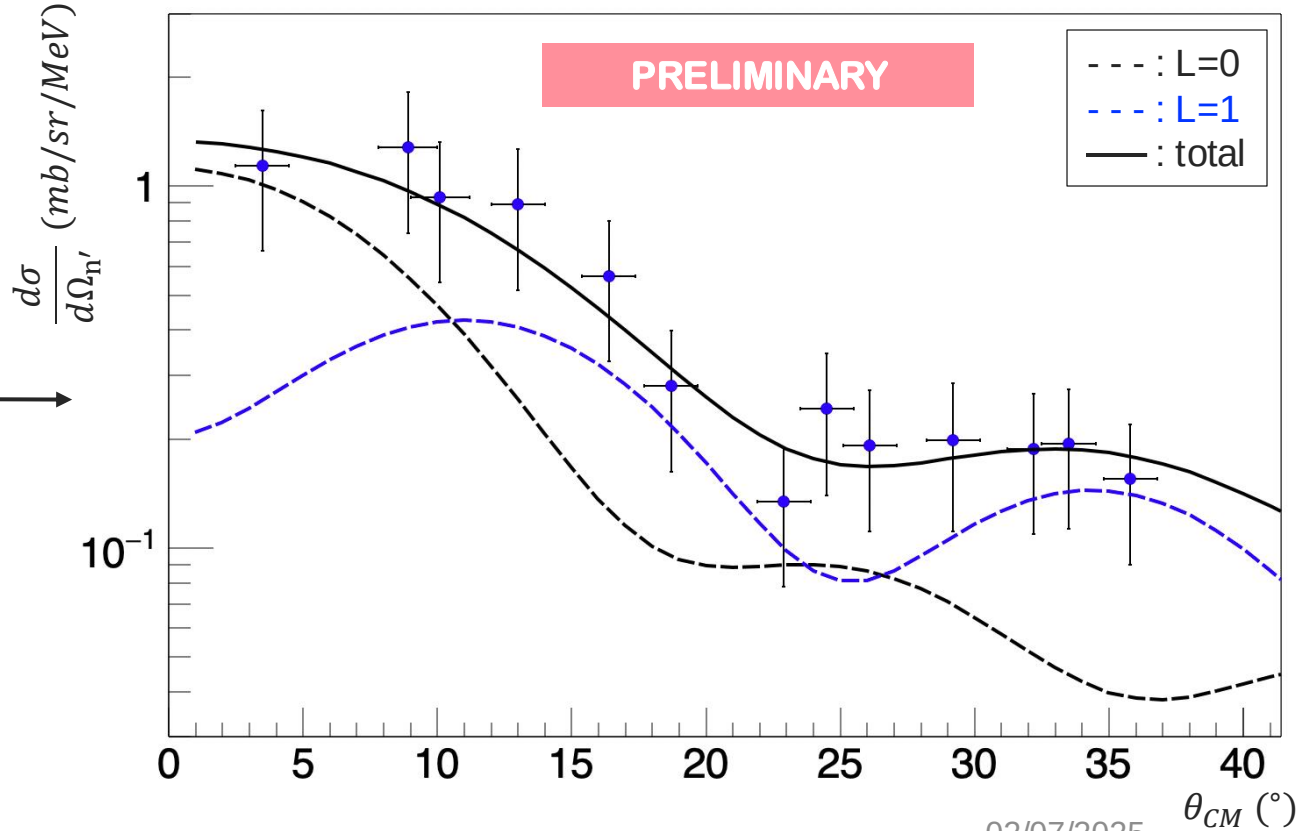

Conclusion

1st experimental study of the **Pygmy Dipole Resonance using neutron inelastic scattering**

- ☑ Experiment in September 2022 @ GANIL-SPIRAL2/**NFS**
- ☑ Benchmarking with:
  - **elastic scattering** on C and Ce targets
  - inelastic scattering with the **2^+ excited state of ^{12}C**
- ☑ **Promising preliminary results** for the study of the PDR in ^{140}Ce via (n,n') inelastic scattering using the scattered neutron observable
- ❑ Next steps of the analysis : **extract the dipole strength distribution**
  - ❑ With the scattered neutron observable
  - ❑ With the γ-ray observable

Thank you for your attention !

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† *Deceased author*