What's new in the calculations of the nuclear excitations and multipole resonances ?

Andrea Porro*
Technische Universität Darmstadt, Department of Physics, 64289 Darmstadt, Germany and
ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany

Mikael Frosini†
CEA, DES, IRESNE, DER, SPRC, 13108 Saint-Paul-lès-Durance, France

Sophie Péru‡
CEA, DAM, DIF, F-91297 Arpajon, France and
Université Paris-Saclay, CEA, LMCE, 91680 Bruyères-le-Châtel, France

Project of the *Espace de Structure et de réactions Nucléaires Théorique*
esnt.cea.fr

18-22 November 2024

CEA Saclay, DPhN, Orme des Merisiers, b. 703, room 135, F-91191 Gif-sur-Yvette

I. SCIENTIFIC ISSUE

In response to the invitation extended by the Scientific Council and "the pilots" of the *Espace de Structure et de réactions Nucléaires Théorique* (ESNT), we propose the organization of a workshop aimed at convening experts in nuclear excitations and multipole resonances. The significance of this initiative was underscored during the ESNT workshop titled "Nuclear energy density functional method: going beyond the minefield" in November 2023. Hence, we believe that discussing current advancements and unresolved issues in this field is both pressing and opportune.

Nuclear multipole resonances represent fundamental phenomena in nuclear physics, elucidating the intricate behaviors of atomic nuclei under external fields or in scattering experiments. These resonances originate from the collective oscillations of nucleons within the nucleus, characterized by various multipole moments, including electric ($E0$, $E1$, $E2$, etc.) and magnetic ($M1$, etc.) moments. They hold a pivotal role in comprehending nuclear structure, reactions, and astrophysical processes. Through the study of these resonances, researchers can acquire insights into the structure of finite nuclei and the dynamics of nuclear reactions, vital for applications ranging from astrophysics to energy production and nuclear medicine.

II. GOALS OF THE PROJECT

The current project encompasses several distinct objectives outlined as follows:

1. Providing a comprehensive overview of state-of-the-art microscopic models that describe collective modes in finite nuclei and their practical applications. Often, practitioners of a specific method are unaware of advancements and potential synergies with other techniques. Introductory sessions will delve into the theoretical foundations of key tools in this domain, such as the Quasiparticle Random Phase Approximation (QRPA), the Shell Model, the Time-Dependent Mean Field (TDMF) and the Projected Generator Coordinate Method (PGCM). This aims to highlight commonalities and disparities between these approaches. Additionally, discussions will focus on utilizing spectroscopic data to study level densities and gamma strength functions, emphasizing their significance in astrophysical contexts.

*Electronic address: aporro@theorie.ikp.physik.tu-darmstadt.de
†Electronic address: mikael.frosini@cea.fr
‡Electronic address: sophie.peru-desenfants@cea.fr

2. Identifying the quantities that can be evaluated using a diverse array of models and experimental data. Experimental analyses frequently necessitate theoretical inputs to extract relevant physical quantities. What are the key inputs demanded from experimental data? Which methodologies can fulfill these demands? Is there significant model dependence in the analysis process?

3. Exploring renewed theoretical interest in describing multi-phonon resonances and their experimental manifestations. Can theoretical frameworks provide clear markers or signatures to identify multi-phonon states experimentally? What is the current theoretical and experimental interest in studying multi-phonon states? Do they serve as a test for the Brink-Axel hypothesis?

4. Facilitating discussions among participants employing different formalisms or frameworks capable of calculating specific quantities in the same system and comparing results. The overarching goal is to foster the creation of a theoretical network equipped to address the needs of the experimental community.

Format of the workshop: The morning sessions will feature comprehensive review lectures, while the afternoons will pivot towards roundtable discussions centered on technical nuances or specific phenomena. Morning lectures aim to introduce various theoretical methodologies relevant to nuclear multipole excitations, along with providing a historical overview and current assessment of experimental developments. Additionally, there will be review presentations focusing on the utilization of spectroscopic theoretical data in practical domains, including evaluations of level densities and gamma strength functions. This endeavor seeks to underscore the significance of precise theoretical predictions across diverse fields such as nuclear data for reaction networks and astrophysics.

III. LIST OF SPEAKERS

Introductory lectures on experimental and historical aspects

- **Yorick Blumenfeld**, IJCLab Orsay , yorick.blumenfeld@ijclab.in2p3.fr
  Giant Multipole Resonances: A chapter in the history of experimental nuclear physics
- **Gianluca Colò**, Università degli Studi di Milano, Gianluca.Colo@mi.infn.it
  Historical introduction on the theoretical description of multipole resonances and open issues
- **Marine Vandebrouck**, CEA Saclay, marine.vandebrouck@cea.fr
  Probing Giant Multipole Resonances today: precision in stable nuclei and new phenomena in unstable ones

Lectures on theoretical methods

- **Danilo Gambacurta**, INFN Catania, gambacurta@lns.infn.it
  The Second RPA and its connection to the nuclear multipole response
- **Denis Lacroix**, IJCLab Orsay, denis.lacroix@ijclab.in2p3.fr
  Time-dependent microscopic description of collective nuclear excitations
- **Jaime Martínez-Larraz**, Universidad Complutense de Madrid, jaime.martinez-larraz@uam.es
  The PGCM and its connection to collective states and resonances
- **Sophie Péru**, CEA Bruyères-le-Châtel, sophie.peru-desenfants@cea.fr
  QRPA for deformed and odd nuclei study and systematic calculations
- **Kamila Sieja**, IPHC Strasbourg, kamila.sieja@iphc.cnrs.fr
  Configuration Interaction Shell Model: applications to dipole excitations of atomic nuclei

Lectures on application

- **Stephane Goriely**, Université Libre de Bruxelles, stephane.goriely@ulb.be
  Level densities and photon strength functions and their impact in astrophysics
- **Stephane Hilaire**, CEA Bruyères-le-Châtel, stephane.hilaire@cea.fr
  Collective excitations and the calculation of level densities and photon strength functions

Round tables on specific aspects, topic and chairperson

- **Mikael Frosini**, CEA Cadarache, mikael.frosini@cea.fr
  Electric versus magnetic modes and pertinence to describe low energy collective state
- **Sophie Péru**, CEA Bruyères-le-Châtel, sophie.peru-desenfants@cea.fr
  Decaying operator and how to include the experiment kinematic in theoretical interpretation of multipolar resonances measurements
- **Andrea Porro**, Technische Universität Darmstadt, aporro@theorie.ikp.physik.tu-darmstadt.de
  Double and multi-phonon states and how to describe and/or identifying them
- **Olivier Roig**, CEA Bruyères-le-Châtel, olivier.roig@cea.fr
  Experimental setup for gamma strength function measurement

Technical talks animating the round tables

- **Stavros Bofos**, CEA Cadarache, stavros.bofos@cea.fr
  Magnetic collective state in the PGCM/Shell Model hybrid approach
- **Marc Dupuis**, CEA Bruyères-le-Châtel, marc.dupuis@cea.fr
  QRPA calculations for reaction modeling
- **Mikael Frosini**, CEA Cadarache, mikael.frosini@cea.fr
  Individual mode extraction within Finite Amplitude Method
- **Luis Gonzáles-Miret**, CEA Bruyères-le-Châtel, luis.gonzales-miret@cea.fr
  Comparison of QFAM RPA strength function from different interactions
- **Oscar Le Noan**, IPHC Strasbourg, oscar.lenoan@iphc.cnrs.fr
  E1 dipole response of light nuclei in valence spaces
- **Andrea Porro**, Technische Universität Darmstadt, aporro@theorie.ikp.physik.tu-darmstadt.de
  Description of multi-phonon states using ab initio PGCM calculations

IV. PRELIMINARY PROGRAM

	Monday	Tuesday	Wednesday	Thursday	Friday
9h30	Blumenfeld	Colò	Martínez-Larraz	Lacroix	Goriely
10h45	**Break**	**Break**	**Break**	**Break**	**Break**
11h15	Vandebrouck	Péru	Sieja	Gambacurta	Hilaire
12h30	**Lunch**	**Lunch**	**Lunch**	**Lunch**	**Lunch**
14h00	Roig	Gonzales Dupuis	Bofos Le Noan	Porro	End of the workshop
15h00	Round table	Round table	Round table	Round table	
16h30	**End**	**End**	**End**	**End**	