



A new near-threshold dipole resonance in ^{10}Be

Autor Autor
Nicholas Keeley



**NATIONAL
CENTRE
FOR NUCLEAR
RESEARCH**
ŚWIERK

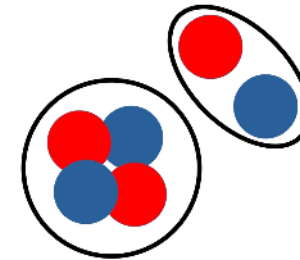
The structure and dynamics of light nuclei form fascinating subjects for investigation. The presence of marked cluster structures is a characteristic property.

Different clustering modes often exist in a single nucleus, in different levels or co-existing in the same level (configuration mixing).

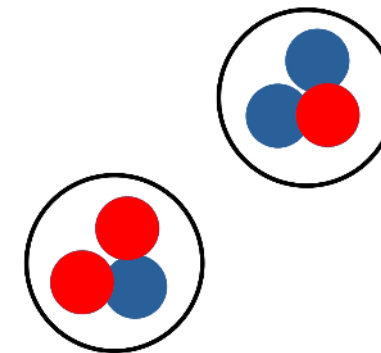
Simple example: ${}^6\text{Li}$. Dominant mode in low-lying levels is $\alpha + d$, but ${}^3\text{He} + t$ also present.

Intrinsically interesting but can also be exploited to probe structure of other nuclei via suitable choice of direct reaction.

$\alpha + d$, threshold 1.47 MeV



${}^3\text{He} + t$, threshold 15.79 MeV



Cluster structures involving the tightly bound α particle are frequently important.

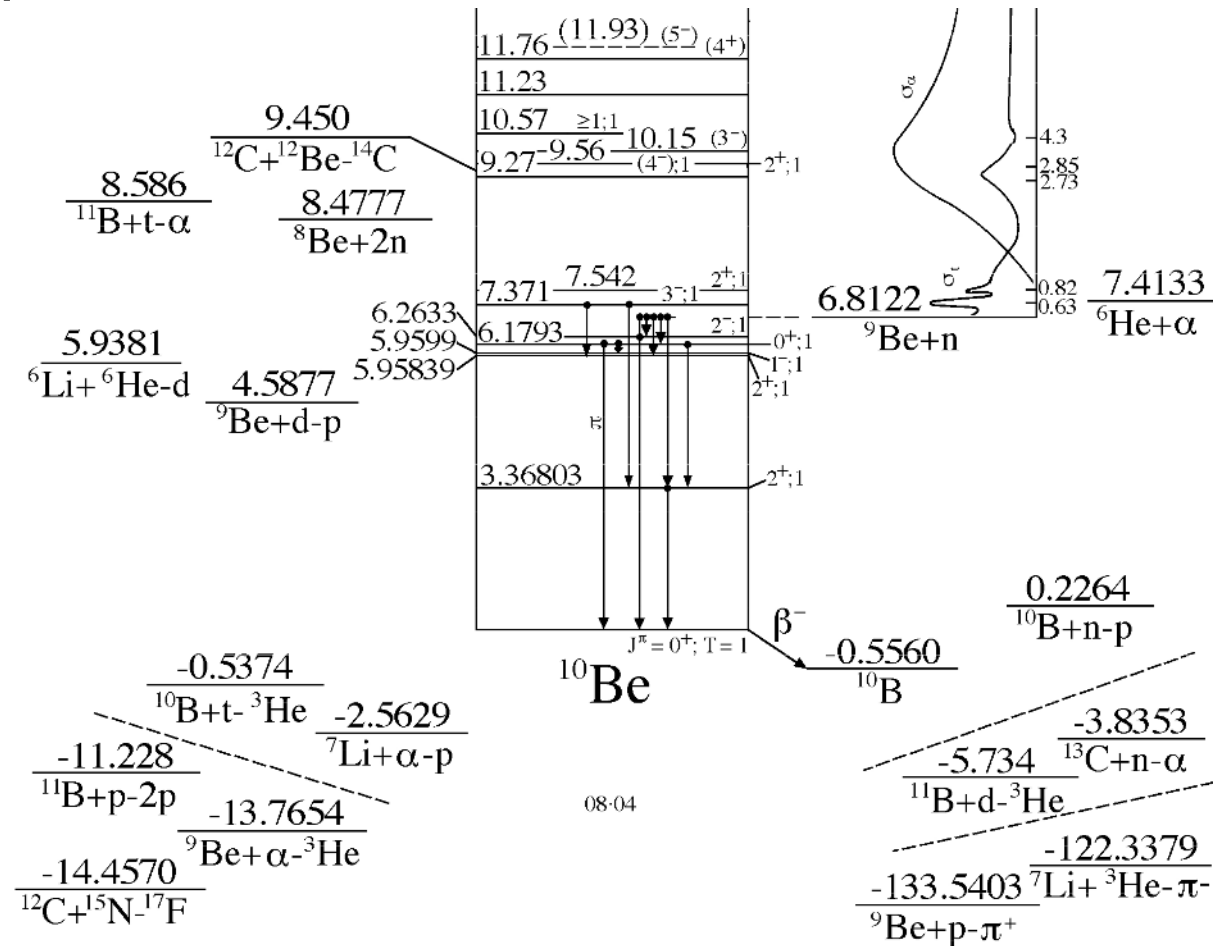
Many of the neutron-rich isotopes may be visualised as either clusters of α particles with neutrons acting as “bonds” or as combinations of α particles and the neutron-rich He isotopes ${}^6\text{He}$ and ${}^8\text{He}$.

These asymmetric clustering modes can manifest as low-energy dipole transitions. The different modes can mix in a single level which thus provides valuable information on the structure.

The ^{10}Be nucleus forms an interesting example of this type, with a number of different clustering possibilities in addition to the four-body $\alpha + \alpha + n + n$ mode.

The energy level diagram for ^{10}Be reveals that the thresholds for emission of n , α and $2n$ are close.

This suggests that levels in ^{10}Be at around $E_{\text{ex}} \approx 7$ MeV may mix different modes.

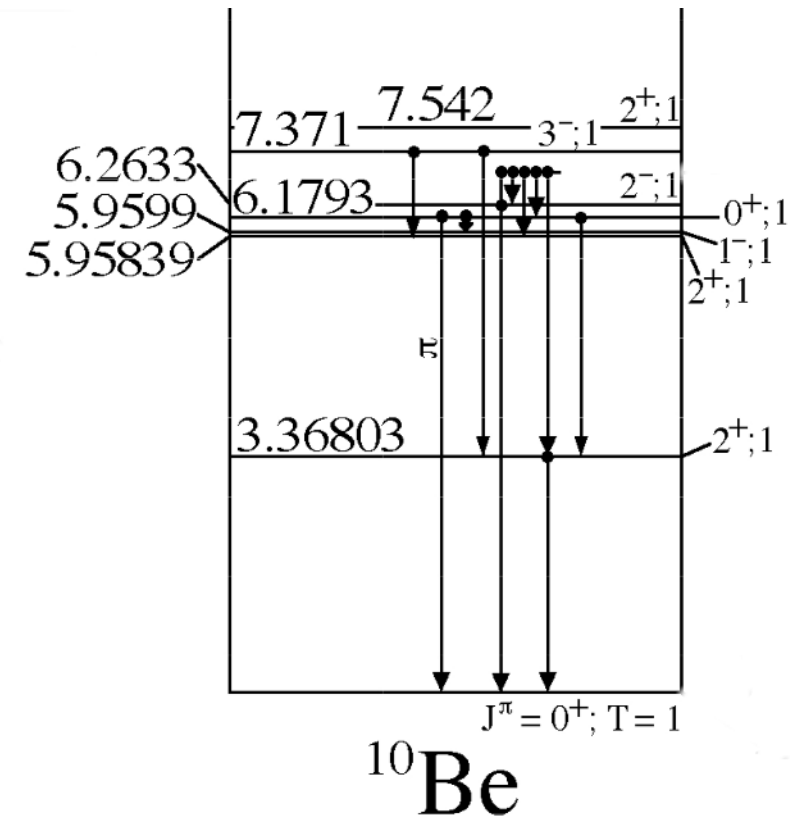
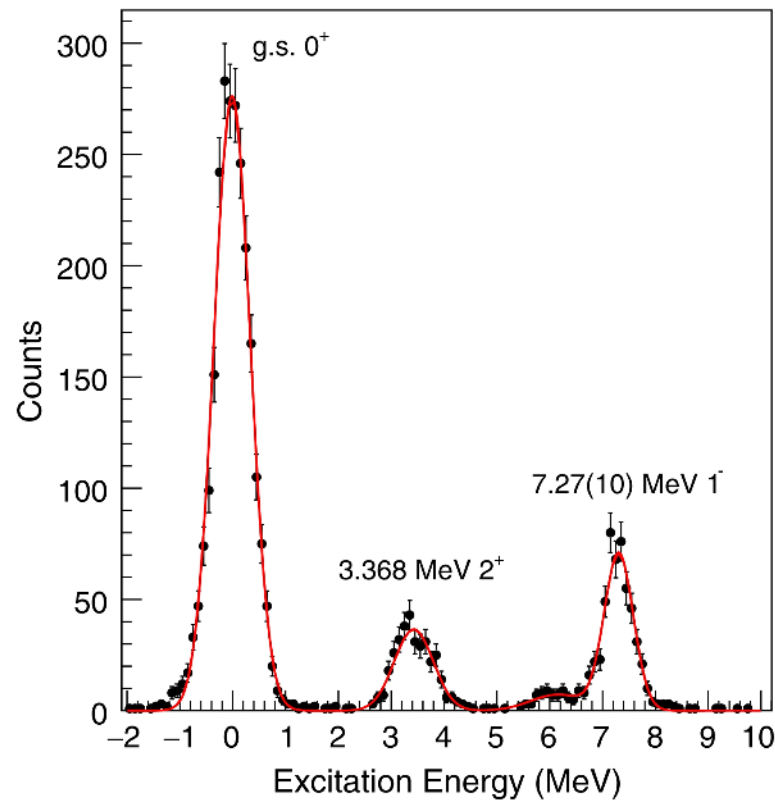


To date, while several low-lying dipole levels have been predicted in ^{10}Be , only one, at $E_{\text{ex}} = 5.960$ MeV, has been observed experimentally. It also has a very small $B(E1)$ value and is thus weakly populated.

A recent experiment carried out at the ReA6 facility of the NSCL at Michigan State University measured the scattering of deuterons from ^{10}Be in inverse kinematics using the AT-TPC.

A 9.6 MeV/u ^{10}Be beam of ≈ 2000 particles per second entered the AT-TPC which was filled with pure deuterium gas at 600 Torr pressure, acting as both target and detector medium.

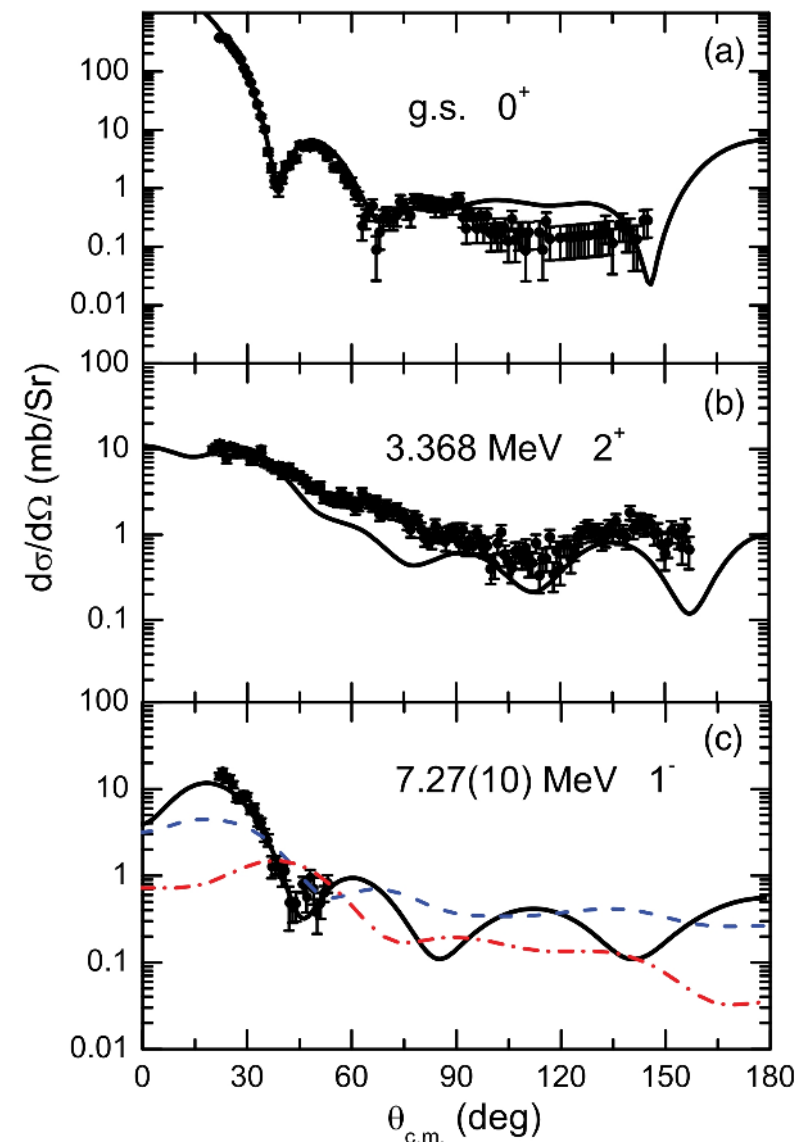
Elastic and inelastic scattering were observed. The well-known 3.368-MeV 2^+ level was cleanly separated, with a weakly populated peak at ~ 6 MeV containing several unresolved levels including the 5.960-MeV 1^- and a strong peak centred at 7.27 ± 0.10 MeV.



The centroid of the 7.27-MeV peak does not correspond with either the known 7.371-MeV 3^- or 7.542-MeV 2^+ levels (although they are not resolved).

Angular distributions were obtained for the elastic scattering and inelastic scattering to the 3.368-MeV 2^+ and the 7.27-MeV peak.

The curves on the angular distribution plots represent coupled channels (CC) fits to the data.



CC is a standard technique for describing inelastic scattering. The inelastic couplings are explicitly included by deforming the diagonal optical potential: we take the derivative and multiply by a strength, the so-called “deformation length” δ .

The inelastic scattering to the 3.368-MeV 2^+ level was fitted with a value of $\delta = 1.89$ fm, in agreement with previous values obtained from proton scattering data [Phys. Lett. B **481**, 7 (2000)].

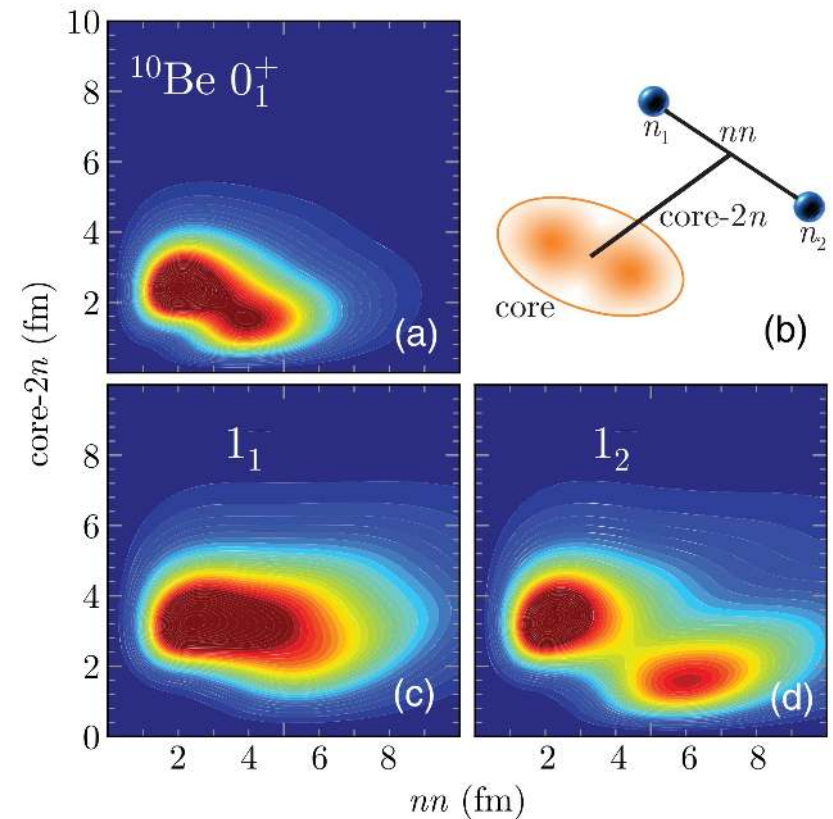
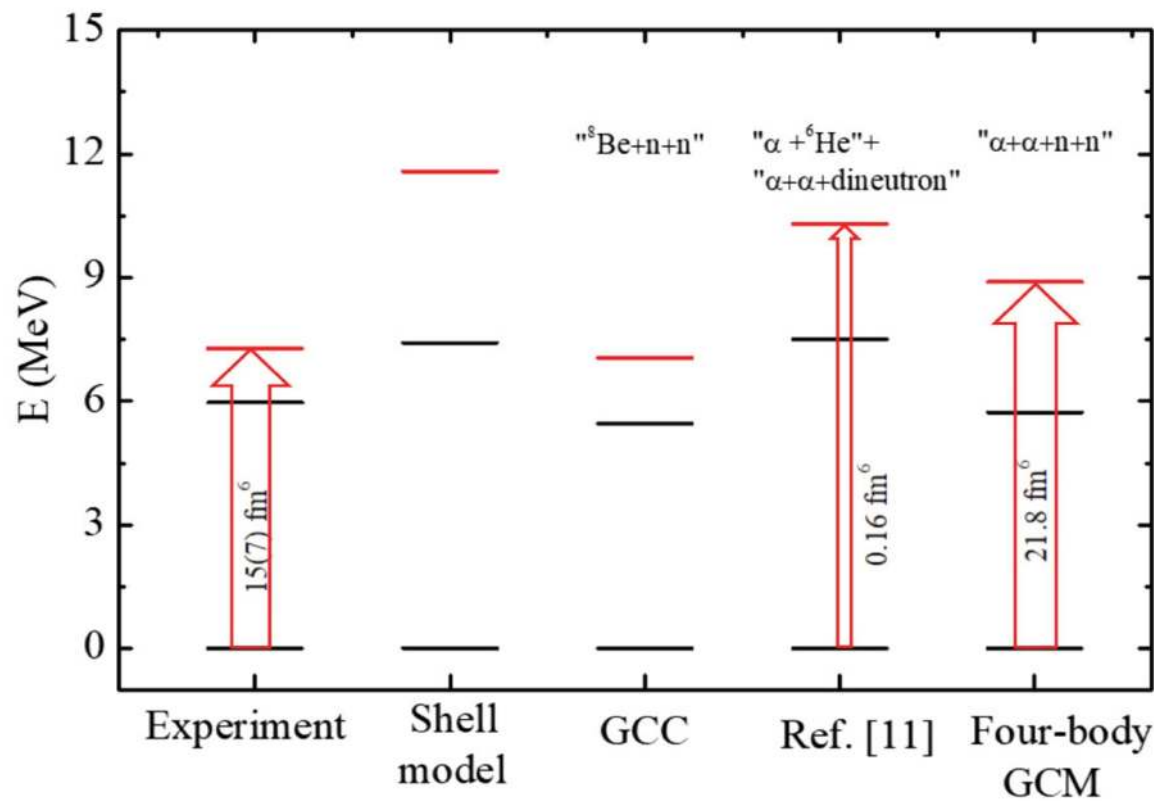
The angular distribution for the 7.27-MeV peak is incompatible with either a 2^+ (dashed blue curve) or a 3^- (dot-dashed red curve) assignment.

A value of $\delta = 0.76$ fm was obtained for the 7.27-MeV level assuming a 1^- assignment, 5-15% of the energy-weighted sum rule (EWSR) for the total dipole strength in ^{10}Be . This is to some extent an upper limit, since some contribution from the 7.371-MeV and/or 7.542-MeV levels to the observed peak cannot be ruled out.

We thus have strong evidence for a new 1^- level in ^{10}Be close to the neutron and α particle emission thresholds. It may possibly be identical with the previously observed 7.371-MeV level, although the 3^- assignment would be incorrect in that case.

How does this compare with structure model calculations?

The Gamow coupled channels (GCC) approach [Phys. Rev. Lett. **126**, 142501 (2021), Phys. Rev. Res. **5**, 023183 (2023)] assuming a ${}^8\text{Be} + 2n$ structure can reproduce the general features of the two 1^- levels:



Near-Threshold Dipole Strength in ^{10}Be with Isoscalar Character

J. Chen^{1,2,*}, Y. Ayyad^{3,†}, D. Bazin⁴, W. Mittig⁴, M. Z. Serikow⁴, N. Keeley⁵, S. M. Wang^{6,7}, B. Zhou,^{6,7}
J. C. Zamora⁴, S. Beceiro-Novo⁸, M. Cortesi⁴, M. DeNudt⁴, S. Heinitz⁹, S. Giraud⁴, P. Gueye⁴, C. R. Hoffman²,
B. P. Kay², E. A. Mauger⁹, B. G. Monteagudo,^{4,10} H. Li¹¹, W. P. Liu,^{1,12} A. Muñoz,³ F. Ndayisabye,⁴ J. Pereira,⁴
N. Rijal,⁴ C. Santamaria⁴, D. Schumann⁹, N. Watwood⁴, G. Votta,⁴ P. Yin¹³, C. X. Yuan¹⁴ and Y. N. Zhang¹⁴

¹*College of Science, Southern University of Science and Technology, Shenzhen 518055, Guangdong, China*

²*Physics Division, Argonne National Laboratory, Lemont, Illinois 60439, USA*

³*IGFAE, Universidade de Santiago de Compostela, E-15782, Santiago de Compostela, Spain*

⁴*FRIB/NSCL Laboratory, Michigan State University, East Lansing, Michigan 48824, USA*

⁵*National Centre for Nuclear Research, ulica Andrzeja Sołtana 7, 05-400 Otwock, Poland*

⁶*Key Laboratory of Nuclear Physics and Ion-beam Application (MOE), Institute of Modern Physics, Fudan University, Shanghai 200433, China*

⁷*Shanghai Research Center for Theoretical Nuclear Physics, NSFC and Fudan University, Shanghai 200438, China*

⁸*Universidade da Coruña, Campus Industrial, Departamento de Física y Ciencias de la Tierra, CITENI, Ferrol 15471, Spain*

⁹*Laboratory of Radiochemistry, Paul Scherrer Institute, Villigen, Switzerland*

¹⁰*Department of Physics, Hope College, Holland, Michigan 49422-9000, USA*

¹¹*Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China*

¹²*China Institute of Atomic Energy, P.O. Box 27547, Beijing 102413, China*

¹³*College of Physics and Engineering, Henan University of Science and Technology, Luoyang 471023, China*

¹⁴*Sino-French Institute of Nuclear Engineering and Technology, Sun Yat-Sen University, Zhuhai 519082, China*

Thank you for your attention



NATIONAL
CENTRE
FOR NUCLEAR
RESEARCH
ŚWIERK

www.ncbj.gov.pl

