DREB2022 - Direct Reactions with Exotic Beams

Sunday, 26 June 2022 - Friday, 1 July 2022

University of Santiago de Compostela

Programme

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Sunday, 26 June 2022

ARRIVAL & REGISTRATION - Casa de Europa (18:00 - 20:00)

Monday, 27 June 2022

Welcome - Facultad de Ciencias de la Comunicación (09:00 - 09:20)

Opening Speakers - Facultad de Ciencias de la Comunicación (09:20 - 10:40)

-Conveners: Maria Jose Garcia Borge

[293] Keynote talk 1: Recent highlights from direct reaction experiments with exotic beams (09:20)

Presenter: KANUNGO, Rituparna

Rare isotopes with their unexpected, hence exotic characteristics, have ushered a new era in nuclear science. This presentation will discuss recent direct reaction experiments that have unveiled new features in rare isotopes. Many of these isotopes play an important role in driving the heavy element synthesis in our universe. The reactions governing the nucleosynthesis are most often not directly accessible to measure in the laboratory. The presentation will show how direct reactions offer surrogate approach to constrain some of them. An outlook on future prospects will be discussed.

[294] Keynote talk 2: Exciting developments in Reaction Theory (10:00)

Presenter: NUNES, Filomena

Reaction theory is an essential component for the science with exotic beams. A variety of reactions probes allow us to explore nuclear properties in regions far away from stability and extract information important for astrophysics. However, the interpretation of these results rely heavily on accurate reaction models to describe the reaction processes. In this overview talk, we will summarize the standard reaction theory methods used in the field, highlighting some recent developments. We will also discuss recent studies to extract the effective interactions that are the ingredients of reaction models, as well as their uncertainties, and close listing some of the challenges that need to be tackled in the future.

Coffee Break - Facultad de Ciencias de la Comunicación (10:40 - 11:20)

MON1 - Facultad de Ciencias de la Comunicación (11:20 - 11:40)

-Conveners: Maria Jose Garcia Borge

[287] What locates neutron driplines ? (11:20)

Presenter: OTSUKA, Takaharu

The neutron dripline is one of the fundamentals of atomic nuclei, and nuclear physics must be able to depict its location and origin. The neutron dripline has now been known up to Na isotopes experimentally. The mean potential provides us with a natural account of the dripline as the uppermost bound orbit, which seems to work for the majority of light nuclei and explain the appearance of neutron halo. However, the dripline of F-Ne-Na isotopes changes as Z, and the general understanding of this trend seemed to be missing. We explored an alternative underlying picture of the dripline, starting from nuclear forces and including full of correlations. This aim was materialized by performing large-scale shell-model calculations using EEdf1 effective interaction derived in an ab initio way from the chiral EFT interaction [1]. It was presented that the dripline mechanism beyond oxygen isotopes differs from the above-mentioned traditional one. The quadrupole deformation produces binding energies and shifts driplines. This contribution is saturated at a certain common neutron number for different isotope chains, contrary to experimental fact. It is demonstrated that on top of this effect, the monopole interaction drives the dripline further away to different extents depending on Z. This monopole-quadrupole interplay indeed explains the variation of the dripline location from F to Na isotopes. This talk will present a pedagogical sketch of this mechanism [2] as the second dripline mechanism after the traditional one based on the single-particle picture. Some related features of exotic Na and Mg isotopes are discussed if time permits, as further relevance to direct reactions in exotic nuclei. [1] N.Tsunoda,T.Otsuka,K.Takayanagi et al., Nature, 587, 66 (2020). [2] T.Otsuka, Physics, 4, 258-285 (2022).

MON2 - Facultad de Ciencias de la Comunicación (11:40 - 13:00)

-Conveners: Jose Benlliure

[210] Cluster states in 14C and 15C studied with the 10Be+9Be reactions (11:40)

Presenter: NURKIĆ, Deni

In this contribution, a brief analysis will be given of an experiment performed at LNS-INFN (July 2018) with a 54 MeV ^{10}Be beam and a ^{9}Be target. The ^{10}Be+^{9}Be reactions are measured to get information on different types of structures of several light nuclei. Special attention is given to a search for cluster states in ^{14}C and ^{15}C. The ^{9}Be isotope has been chosen as the experimental target because of the existence of a cluster structure ^{5}He+^{4}He inside its ground state. Such target structure, alongside the choice of the ^{10}Be radioactive beam with a suitable energy of 54 MeV, means that the transfer of one of the aforementioned clusters from the target to the beam should result in the creation of the sought ^{14}C or ^{15}C isotopes. This should be followed by sequential decay into several channels, some of which are ^{4}He + ^{10}Be for ^{14}C and ^{4}He + ^{11}Be or ^{6}He + ^{9}Be for ^{15}C. If we manage to see the experimental signature of these processes, this would be the first indication of the existence of cluster states inside the ^{15}C nucleus, while a positive result for the ^{14}C isotope would help to clear up the contradicting findings of other authors. The experimental setup consists of four highly segmented telescopes covering polar angles from 20° to 90° which enable particle identification using traditional ${\Delta}$E-E techniques. E part of the telescope is a double-sided silicon strip detector divided into 16 strips at each side, while the ${\Delta}$E part is one-sided with 16 strips. Preliminary results for the reaction channels of interest will be shown. Plans for the remaining analysis will also be included.

[217] The search for the tetraneutron (12:00)

Presenter: DUER, Meytal

Whether multi-neutron systems can exist as weakly bound states or very short-lived unbound resonant states has been a long standing quest. The experimental search for such systems has been going for six decades, with a particular focus on the four-neutron system, the tetraneutron, resulting in up to date only few indications for its existence. In this talk I will present a recent experiment performed at the RIKEN Nishina Center in Japan. The measurement was conducted at the SAMURAI setup using the quasi-elastic knockout of an alpha particle from a high-energy 8He projectile induced by a proton target to populate a possible tetraneutron state.

[211] Bound-to-continuum potential model for nucleon radiative capture reaction in nuclear astrophysics (12:20)

Presenter: BUI, Minh-Loc

The nucleon radiative capture reactions in which the nucleon is absorbed by the target nucleus, and the gamma radiation is then detected are important in pure and applied nuclear physics, especially in nuclear astrophysics. Radiative capture cross sections at very low energies are inaccessible by experiments, but are important for astrophysical studies. In our work, the keV-nucleon radiative capture reactions were studied using the bound-to-continuum potential model in which both scattering and bound states are based on the Skyrme Hartree-Fock calculation. The obtained results are shown to be in good agreement with the available experimental data, and the extrapolation at very low energies near 0 keV is reliable. The properties of the single-particle states of the residual nuclei are also discussed.

[216] STRASSE: A silicon tracker for quasi free scattering measurement at the RIBF (12:40)

Presenter: ALCINDOR, Valérian

STRASSE (Silicon Tracker for RAdioactive-nuclei Studied at SAMURAI Experiments) is a tracker and cryogenic target for studying the structure of atomic nuclei at the RIKEN accelerator in Japan. Exploring the evolution of the nuclear structure towards the drip line, as characterized by the changes of magic numbers, deformations, and clustering structures, is a major focus in modern nuclear physics. Exotic combinations of protons and neutrons can significantly affect the underlying shell structure, and for weakly bound nuclei at or near the dripline, the proximity to continuum states may further alter nuclear properties. Benchmarking and constraining theory at the very limits of existence is critical. However, from the experimental point of view, the accessibility to the most exotic species is usually limited by the very low production intensities for these nuclei. STRASSE's thick LH2 target will compensate for these low rates, while its compact silicon tracker array will ensure satisfactory missing mass resolution with excellent ~0.5 mm reaction vertex resolution (FWHM). STRASSE will be coupled to the high-efficiency array CATANA (Cesium iodide Array for γ-ray Transitions in Atomic Nuclei at high isospin Asymmetry) with a radius of □20 cm to detect gamma rays in coincidence and measure the total kinetic energy of recoil protons at RIBF. This new device will allow us to combine in-beam gamma-ray and missing mass spectroscopy.

Lunch Break - Facultad de Ciencias de la Comunicación (13:00 - 14:40)

MON3 - Facultad de Ciencias de la Comunicación (14:40 - 16:20)

Chair: Peter Higgs

-Conveners: Thomas Aumann

[291] Open quantum system behavior of a near threshold resonance in 11B (14:40)

Presenter: MITTIG, Wolfgang

A narrow near-threshold proton-emitting resonance (Ex=11.4 MeV,Jπ= 1/2+ and Γp= 4.4 keV) was directly observed in ^{11}B via proton resonance scattering. This resonance was previously observed in the β-delayed proton emission of the neutron halo nucleus ^{11}Be [1].The good agreement between both experimental results serves as a ground to confirm the existence of such exotic decay and the particular behavior of weakly bound nuclei as open quantum systems. R-matrix analysis and single-particle resonance show in agreement with the data that the resonance effect reaches far beyond the resonance width due to the fast increase of penetrability in this below-barrier domain. This unusual behavior can be considered as paradigm of an open quantum system. The shape of the resonance, a consequence of the interplay between the reaction mechanism and structure,clearly reveals the open quantum system nature of such narrow resonances. The resonance properties will be discussed with respect to the spectroscopic factor as obtained from R-matrix analysis and will be compared to arecent study of the same resonance by a transfer reaction10Be(d,n) [2]. [1] Y. Ayyad et al., Phys. Rev.Lett.123, 082501 (2019) [2] E. Lopez Saavedra et al., in APS Division of Nuclear Physics Meeting Abstracts, Vol. 2021(2021) pp. EF–006.

[227] Systematics of reaction cross sections and geometrical parameters from double folding and single folding optical potentials (15:00)

Presenter: MOUMENE, Imane

At the moment a hot topic of research is the description of the residual-nucleus-target part of knockout reactions from exotic projectiles with large differences in the valence neutron-proton separation energies. Comparing a large set of theoretical and experimental reaction cross-sections, for some light projectiles on a 9Be, we provide a quantitative assessment of the description of the core-target part of knockout reactions. We also show that a single-folded (s.f.) (light-) nucleus-9Be imaginary optical potential is more accurate than a double-folded (d.f) optical potential. Within the eikonal formalism for the cross sections and phase shifts, the single-folded potential is obtained using a n-9Be phenomenological optical potential and microscopic projectile densities. Our results show that the (s.f.) cross sections are larger than the (d.f.) cross sections and the effect increases with the target mass. Furthermore the strong absorption radius parameter extracted from the S matrices of (s.f.) results has a stable value rs =1.3 - 1.4 fm for all target masses and a very small dependence on the asymmetry of the valence neutron and proton separation energies in the projectile. This indicates that a clear geometrical separation can be made between the region of surface quasi elastic reactions and the region of strong absorption into other channels because of which the residual nucleus will not survive intact. The (d.f.) results are instead much scattered and the separation between surface reactions and other channel is not consistent.

[220] Spectroscopy of the T=3/2, A=47 and A=45 Mirror Nuclei via One- and Two- Nucleon Knockout Reactions (15:20)

Presenter: UTHAYAKUMAAR, Sivahami

Spectroscopy of the T=$\frac{3}{2}$, $A=47$ and $A=45$ Mirror Nuclei via One- and Two- Nucleon Knockout Reactions S. Uthayakumaar^{1}, M. A. Bentley^{1}, E. C. Simpson^{2}, T. Haylett^{1}, R. Yajzey^{1,3}, S. M. Lenzi^{4}, W. Satula^{5}, D. Bazin^{6,7}, J. A. Belarge^{6}, P. C. Bender^{6}, P. J. Davies$^{}$, B. A. Elman^{6,7}, A. Gade^{6,7}, H. Iwasaki^{6,7}, D. Kahl^{8,9}, N. Kobayashi^{6}, B. R. Longfellow^{6,7}, S. J. Lonsdale^{8}, E. M. Lunderberg^{6,7}, L. Morris^{1}, D. R. Napoli^{10}, T. G. Parry^{11}, X. Pereira-Lopez^{1,12}, F. Recchia^{4,6}, J. A. Tostevin^{11}, R. Wadsworth^{1} and D. Weisshaar^{6} ^{1}Department of Physics, University of York, Heslington, York, YO10 5DD, United Kingdom, ^{2}Research School of Physics, The Australian National University, Canberra ACT 2600, Australia, ^{3}Department of Physics, Faculty of Science, Jazan University, Jazan 45142, Saudi Arabia, ^{4}Dipartimento di Fisica e Astronomia dell'Università and INFN, Sezione di Padova, I-35131 Padova, Italy, ^{5}Institute of Theoretical Physics, Faculty of Physics, University of Warsaw, ul. Pasteura 5, PL-02-093, Warsaw, Poland, ^{6}National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, MI 48824, USA, ^{7}Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824, USA, ^{8}School of Physics and Astronomy, University of Edinburgh, Edinburgh EH9 3FD, United Kingdom, ^{9}Extreme Light Infrastructure – Nuclear Physics, Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), 077125 Bucharest-Măgurele, Romania, ^{10}INFN, Laboratori Nazionali di Legnaro, I-35020 Legnaro, Italy, ^{11}Department of Physics, Faculty of Engineering and Physical Sciences, University of Surrey, Guildford, Surrey GU2 7XH, United Kingdom, ^{12}Center for Exotic Nuclear Studies, Institute for Basic Science (IBS), Daejeon 34126, Republic of Korea The study of nuclei close to the N=Z line region on the nuclear chart provides a pathway to investigate proton-rich systems that are in proximity of the proton drip line. The phenomenon of isospin symmetry, which plays a key role when examining nuclei either side of the line of N=Z, occurs due to the exchange symmetry between protons and neutrons resulting from the near-identical nuclear force between the two types of nucleon. Isobaric analogue states can be compared to understand the various factors that could cause isospin symmetry to be violated [1]. To develop our understanding of isospin symmetry breaking effects, an in-beam gamma-ray spectroscopic study of the exotic proton-rich 47Mn and 45Cr systems was performed through one- and two-neutron knockout reactions from the radioactive 48Mn and 47Cr beams delivered by the NSCL facility, respectively. The analogue one- and two-proton knockout reactions from 48V to 47Ti (the mirror of 47Mn) and 47V to 45Sc (the mirror of 45Cr) were also performed. This novel approach – i.e. `mirrored' knockout reactions – allows for detailed comparison of both the analogue reaction processes (i.e. -1n, -2n and -1p, -2p from a pair of mirror nuclei, respectively) and of the subsequent level schemes of the resulting mirror pair products. Through comparison of the corresponding mirrored reactions, and by exploiting the direct nature of the process, a confident identification can be made of the states in the unknown proton-rich systems being studied – i.e. 47Mn and 45Cr in this case. This also allows the measurement of analogue spectroscopic cross sections, on a state-by-state basis, in these analogue knockout reactions. The measurement of such analogue reactions also has the capability to inform discussion about suppression of spectroscopic strength in knockout reactions – see ref [2]. The experiment was performed at the National Superconducting Cyclotron Facility (NSCL) with the radioactive beams selected by the A1900 fragment separator. The beams impinged onto a 9Be target to produce the pair of analogue nuclei, 47Mn/47Ti and 45Cr/45Sc. Prompt gamma-rays were detected by the state-of-the-art tracking array, GRETINA, with the resulting residues detected and identified using the S800 spectrometer. The latest results from the analysis of 47Mn and 45Cr will be presented, including partial level schemes, a mirror-energy difference analysis and a comparison of the analogue reactions. The comparison of the results from shell-model calculations to a recently developed DFT approach [3] will also be presented. [1] M. A. Bentley and S. Lenzi, Progress in Particle and Nuclear Physics., 59 (2), 497 (2007) [2] J. A. Tostevin and A. Gade, Phys. Rev. C. 103, 054610(2021) [3] W. Satuła, P. Bączyk, J. Dobaczewski, and M. Konieczka, Phys. Rev. C. 94, 024306 (2016)

[280] Isospin dependence of NN correlations, quenching of spectroscopic factors, and effects on other nuclear structure observables (15:40)

Presenter: PETRI, Marina

Although the atomic nucleus consists of strongly interacting nucleons, it is noteworthy that for such strongly interacting quantum system the independent-particle model is proven to be a valid approximation and has provided a basic framework to explain many properties of nuclei. However, correlations between the nucleons, both of short- and long-range nature, modify the mean-field approximation and dilute the pure independent-particle picture. Notably, these correlations are thought to be the reason for the quenching of spectroscopic factors observed in (e,e'p), (p,2p) and single-nucleon direct reactions [1]. Following from the observed increase of the high-momentum component of the proton momentum density in a neutron-rich nucleus [2], we proposed a phenomenological approach to examine the role of NN short- and long-range correlations and their evolution in asymmetric systems [3]. The model predictions correlate well with the reduced proton occupancies for states below or near the Fermi level [4,5], as a function of the asymmetry (N-Z)/A, and also shed light on the question of quenching in intermediate energy single-nucleon knockout on complex targets [6]. In this talk I will discuss our work [3] and further implications of our approach to other low-energy nuclear structure observables. [1] W. Dickhoff and C. Barbieri, Prog. Part. Nucl. Phys. 52 (2004) 377. [2] M. Duer, et al., Nature 560 (2018) 617. [3] S. Paschalis, M. Petri, A.O. Macchiavelli, O. Hen, and E. Piasetzky, Phys. Lett. B 800 (2020) 135110. [4] G. Kramer, H. Blok and L. Lapikas, Nucl. Phys. A679 (2001) 267. [5] L. Atar, et al., Phys. Rev. Lett. 120 (2018) 052501. [6] J. A. Tostevin and A. Gade, Phys. Rev. C 103 (2021) 054610.

[282] Global optical potential from chiral EFT and applications to charge-exchange reactions (16:00)

Presenter: WHITEHEAD, Taylor Ray

The study of exotic nuclei will offer direct insights into fundamental questions in physics, such as the nucleosynthesis of heavy elements and the structure of neutron stars. As rare isotope beam facilities around the world extend their reach to increasingly exotic regions of the nuclear chart, reaction theory models with robust error estimates will be crucial to drive scientific discovery. In particular, nucleon-nucleus optical potentials play a central role in the analysis of a wide range of nuclear reaction experiments, yet to date the most widely applicable optical model potentials are largely phenomenological and lack uncertainty quantification. The recently constructed Whitehead-Lim-Holt (WLH) global optical potential, on the other hand, offers a microscopic description of nucleon-nucleus scattering over a large range of isotopes and scattering energies with error estimates from chiral effective field theory. In this presentation, I will preview several applications of the WLH optical potential in nuclear reactions and natural extensions to nuclear astrophysics. I will also discuss the Bayesian uncertainty quantification of charge-exchange reactions and how they connect to the nuclear equation of state.

Coffee Break - Facultad de Ciencias de la Comunicación (16:20 - 16:50)

MON4 - Facultad de Ciencias de la Comunicación (16:50 - 17:50)

-Conveners: Thomas Aumann

[246] Neutron intruder states above N=50 studied by neutron knockout with HiCARI@RIBF (16:50)

Presenter: PLAGNOL, Leo

The recent spectroscopy of ⁷⁸Ni [1] together with indications of shape coexistence just below the N=50 shell closure for ⁷⁹Zn [2] suggests that deformed intruder configurations could play a crucial role in low-energy structure properties in this region and towards the limits of the nuclear chart. Such configurations are predicted to originate from multiparticle-multihole excitations [3] above the N=50 and Z=28 shell gaps pushed down in energy due to neutron-proton correlations which enhance quadrupole collectivity. Quantifying the way collectivity develops nearby ⁷⁸Ni is crucial since it influences binding energies and the drip-line location [4] with consequences on nucleosynthesis calculations relying on these inputs. Because these intruder states involve many-particle excitations more difficult to describe theoretically, their predicted energies vary more drastically between models [1] than for yrast states originating from "normal" configurations on which they tend to agree. Identifying direct signatures of these intruder configurations is thus of prime interest to benchmark microscopic models or to constrain effective interactions. This topic is the main goal of an experiment performed at the RIBF facility (RIKEN, Japan) in November 2020 to identify and characterize for the first time 2p-1h intruder states in ⁸³Ge and ⁸¹Zn. Neutron hole states in these two N=51 nuclei were populated via neutron knockout reaction from N=52 nuclei ⁸⁴Ge and ⁸²Zn, both having about two neutrons in the $s_{1/2}d_{5/2}$ valence space above N=50. This direct reaction allows in some cases to remove one of the neutrons from the quasi-full $g_{9/2}$ orbital below N=50 to selectively populate the 9/2+ intruder states based on a $\nu(g_{9/2})^{-1}(s_{1/2}d_{5/2})^{+2}$ configuration. The necessary secondary beam were produced at the RIBF by in-flight fragmentation-fission of ²³⁸U and selected in the BigRIPS spectrometer while the ZeroDegree spectrometer allows the identification of nuclei after the reaction. In order to identify the populated states, gamma-rays from their in-flight decay were measured using the HiCARI (High-resolution Cluster Array at RIBF) Germanium array composed of 6 Miniball triple clusters, 4 Clovers and two Gretina-type tracking detectors. The analysis being still ongoing, we propose to present mainly preliminary results for ⁸²Ge (known 2$_{1}^{+}$ and 4_{1}^{+} states populated and used as a benchmark) and for ⁸³Ge (main goal of this experiment). A contributed talk or a poster would be accepted. [1] R. Taniuchi et al., Nature 569, 53 (2019). [2] X. Yang et al., Physical Review Letters 116 (2016). [3] K. Heyde and J. L. Wood, Rev. Mod. Phys. 83, 1467–1521 (2011). [4] J. Erler et al., Nature 486, 509 (2012).

[241] New developments for the modeling of double charge-exchange reactions (17:10)

Presenter: COLONNA, Maria

Charge-exchange reactions offer the possibility to explore the features of the isospin and spin-isospin channels of the nuclear interaction and associated nuclear structure properties. For instance, they have been recently exploited to measure, in inverse kinematics, the spin-isospin response of neutron drip-line nuclei, such as in the case of the 6He(p,n)6Li reaction, and to scrutinize, via the double charge exchange reaction 4He(8He,alpha alpha)4n, the nature of the tetraneutron system. Owing to the analogies between the vertices of the strong and weak interactions in the isospin and spin-isospin channels, charge-exchange reactions are often investigated also to deduce information on nuclear transition matrix elements (NME) relevant for beta decay. In particular, double charge exchange reactions could allow one to probe NME similar to the ones involved in neutrino-less double beta decay. In this contribution we discuss new developments related to the theoretical description of double charge exchange (DCE) reactions. The latter are modeled by a sequential meson-exchange, corresponding to a double single charge exchange (DSCE) reaction mechanism [1]. The crucial role of the ion-ion elastic interactions, in the entrance and exit channels, is discussed. This allows one to single out reaction and structure components from the DCE reaction cross section, with the possibility to extract projectile and target DCE NMEs [2]. As a first application, calculations are performed for the reaction 40Ca(18O,18Ne)40Ar and results are compared to the data measured at LNS-Catania and published by the NUMEN Collaboration (see Refs. in [1]). The possible role of short range n-n correlations, which could correlate the two single charge changing processes yielding the DCE, is also discussed [3]. References: [1] J.I.Bellone et al., Phys. Lett. 807, 135528 (2020). [2] H.Lenske, J.I.Bellone, M. Colonna, D.Gambacurta, Universe 7, 98 (2021). [3] H.Lenske, M.Cavallaro, F.Cappuzzello, M.Colonna, Progr. in Part. and Nucl. Phys. 109, 103716 (2019).

[273] Merging structure and reactions in (d, p) processes (17:30)

Presenter: POTEL, Gregory

Progress on the capability to produce rare-isotopes beams (RIBs [1–3]) has pushed the exploration frontier into remote parts of the nuclear chart far from the valley of stability. The expectation that our traditional knowledge would be challenged as one treads through these exotic nuclear regions has been experimentally confirmed. A striking example is provided by the emergence of new magic numbers, i.e the number of nucleons that fill major shells. Magic numbers are one of the cornerstones of nuclear structure, and nuclei with magic numbers of protons and/or neutrons display a larger stability compared to their close neighbors. Within this context, the phenomenon of parity inversion in N = 7 unstable isotones is associated with the vanishing of the N = 8 shell closure in the corresponding nuclei, and the emergence of N = 6 as an exotic magic number. Another recent example is the experimental evidence of new doubly-magic features in the short-lived 52,54 Ca. The small binding energy displayed by neutron-rich systems entails specific theoretical challenges associated with the proximity of the continuum to the Fermi energy of such nuclei. Recent experiments have even demonstrated the possibility to address the single-particle spectroscopy of unbound nuclei, as testified, for example, by the population of 10 Li resonances in a 9 Li(d, p) experiment [4, 5]. We present a framework for A(d, p)B reactions which merges the microscopic approach to computing the properties of the nucleon-target systems and the three-body n + p + A reaction formalism, thus providing a consistent link between the reaction cross sections and the underlying microscopic structure. In this first step toward a full microscopic description, we focus on the inclusion of the neutron-target microscopic properties, encapsulated in the Green's function. Subsequently, this many-body information is introduced in the few-body Green's Function Transfer approach to (d, p) reactions [6–8]. Aside from a coherent integration of the structure and reactions aspects of the process under study, this formalism also provides a natural description of the continuum. We illustrate the flexibility of the theoretical framework by showing results obtained in very different contexts, namely the population of dipole states close to the neutron separation energy in Pb [9] and Sn [10] isotopes (making use of the quasiparticle phonon model (QPM) description of the structure) and 10 Li, described in Nuclear Field Theory [11]. References [1] http://www.nupecc.org/index.php?display=lrp2016/main. [2] G. Bollen. Frib - facility for rare isotope beams. In AIP Conference

Proceedings, volume 1224, pages 432–441, 2010. [3] O. Kester and H. Stöcker. FAIR project at GSI. World Scientific Publishing Co, 2016. [4] M. Cavallaro, M. De Napoli, F. Cappuzzello, S. E. A. Orrigo, C. Agodi, M. Bondí, D. Carbone, A. Cunsolo, B. Davids, T. Davinson, A. Foti, N. Galinski, R. Kanungo, H. Lenske, C. Ruiz, and A. Sanetullaev. Investigation of the 10 Li shell inversion by neutron continuum transfer reaction. Phys. Rev. Lett., 118:012701, 2017. [5] A.M. Moro, J. Casal, and M. Gómez-Ramos. Investigating the 10 Li continuum through 9Li(d, p)10 Li reactions. Physics Letters B, 793:13, 2019. [6] Jin Lei and A. M. Moro. Reexamining closed–form formulae for inclusive breakup: Application to deuteron–and 6 Li–induced reactions. Phys. Rev. C, 92:044616, 2015. [7] B. V. Carlson, R. Capote, and M. Sin. Elastic and inelastic breakup of deuterons with energy below 100 MeV. arXiv:1508.01466 [nucl-th], 2015. [8] G. Potel, G. Perdikakis, B. Carlson, M. C. Atkinson, W. Dickhoff, J. Escher, M. Hussein, J. Lei, W. Li, A. O. Macchiavelli, A. M. Moro, F. M. Nunes, S. D. Pain, and J. Rotureau. Toward a complete theory for predicting inclusive deuteron breakup away from stability. Eur. Phys. J. A, 53:178, 2017. [9] M. Spieker, A. Heusler, B. A. Brown, T. Faestermann, R. Hertenberger, G. Potel, M. Scheck, N. Tsoneva, M. Weinert, H.-F. Wirth, and A. Zilges. Accessing the single-particle structure of the pygmy dipole resonance in 208Pb. Phys. Rev. Lett., 125:102503, 2020. [10] M. Weinert, M. Spieker, G. Potel, N. Tsoneva, M. Müscher, J. Wilhelmy, and A. Zilges. Microscopic structure of the low-energy electric dipole response of 120 Sn. Phys. Rev. Lett., 127:242501, 2021. [11] F. Barranco, G. Potel, E. Vigezzi, and R. A. Broglia. 9 Li(d, p) reaction as a specific probe of 10 Li, the paradigm of parity-inverted nuclei around the N = 6 closed shell. Phys. Rev. C, 101:031305, 2020.

Coctail @ Colegio Fonseca (20:00 - 21:00)

Tuesday, 28 June 2022

TUE1 - Facultad de Ciencias de la Comunicación (09:00 - 10:40)

-Conveners: Angela Bonaccorso

[208] Direct reactions probed in inverse kinematics with the ISOLDE Solenoidal Spectrometer - recent highlights (09:00)

Presenter: SHARP, David

The ISOLDE Solenoidal Spectrometer (ISS) has been developed to study direct reactions with exotic beams produced at the ISOLDE facility, CERN and is based on the solenoid concept successfully deployed in the HELIOS spectrometer at Argonne National Laboratory [1,2] and now also SOLARIS at FRIB. ISS was successfully fully commissioned during 2021 and the first physics campaign took place using the new position-sensitive silicon array constructed by the University of Liverpool. This talk will present a technical overview of ISS. A number of preliminary highlights from the physics campaign will also be presented. These include a measurement to probe changing shell structure in to the $N=20$ island of inversion via a measurement of the d(^{30}Mg,p)^{31}Mg reaction. Also, at the other end of the nuclear chart, a measurement of the d(^{212}Rn,p)^{213}Rn reaction identified excited states outside N=127. This measurement provides the first spectroscopy of low-lying, single-particle levels in 213Rn. These data will contribute to our understanding of the evolution of single-particle structure outside the N=126 closed neutron shell. [1] A.H.Wuosmaa et al. Nucl. Instrum. Methods Phys. Res., Sect. A **580**, 1290 (2007). [2] J.C.Lighthall et al. Nucl. Instrum. Methods Phys. Res., Sect. A **622**, 97 (2010).

[264] OEDO -- Slowing-Down Beam Line in RIKEN RIBF (09:20)

Presenter: SHIMOURA, Susumu

The RI beam factory (RIBF) at RIKEN has expanded the variety of nuclides, which provides numerous kinds of exotic isotope beams over the nuclear chart by using the in-flight fission or the projectile fragmentation reactions of U or other heavy ions at 345 A MeV. Because of the relatively high energy of the primary beam, typical energies of RI beams for in-beam secondary reaction have been restricted to an energy region typically above 200 A MeV. The deceleration of such intense RI beams provided in the RIBF enables us the further research based on exotic nuclei/exotic states by using low-energy reactions such as transfer reaction, fusion-like reaction and so on. In order to realize this, we have set up OEDO (Optimized Energy Degrading Optics for RI beam) project1), where a new energy-degrading beam line in the RIBF have been constructed consisting of two quadrupole magnets, an RF electric deflector and a mono-energetic degrader. An application of energy degrader at dispersive focus is a general method to degrade the beam energy, while it induces the broadening of beam spot. In the OEDO beam line, an RF electric deflector is employed as focusing element based on the time structure of the beam bunch corresponding to the velocities of the ions. The basic idea, the design, the performances in the commissioning experiment, and some physics experiments are presented as well as possible future physics programs and applications. This work was funded by ImPACT Program of Council for Science, Technology and Innovation (Cabinet Office, Government of Japan) and was supported by Japan Society for the Promotion of Science (JSPS) KAKENHI Grant Number JP16H02177. 1) S. Michimasa et al., Prog. Theor. Exp. Phys. 2019, 043D01 (2019) 2) J.W. Hwang et al., Prog. Theor. Exp. Phys. 2019, 043D02 (2019)

[275] Cluster structure of neutron-rich beryllium isotopes probed by cluster knockout reactions in inverse kinematics (09:40)

Presenter: LI, Pengjie

Clustering is a well-established feature of atomic nuclei needed to develop the complete understanding of the structure of nuclei and fundamental nuclear interactions. So far alpha clustering has dominated cluster states studies among all other possible partitioning. While it is known to manifest itself near alpha threshold in stable N=Z nuclei [1], clustering in the ground-state of exotic nuclei with large imbalance of proton and neutron number is still a question. Neutron-rich beryllium isotopes 10Be,12Be,14Be are the very appealing candidates of clustering studies as being built on the well-developed alpha-alpha rotor of 8Be (N=4, Z=4). It is predicted by calculations in antisymmetrized molecular dynamics model that alpha clustering in the ground-state develops from 10Be going to the dripline [2]. The SAMURAI12 experiment performed at the Radioactive Isotope Beam Factory (RIBF) in RIKEN aims to investigate the cluster structure of neutron-rich beryllium isotopes using the cluster quasifree scattering reaction (p,pa) in inverse kinematics. The reaction of interest was induced by beams of 10,12,14Be isotopes at 150MeV/u impinging on a pure solid hydrogen target with large diameter and 2 mm thick. The detection of helium residues was performed by using the SAMURAI spectrometer and its standard detectors. Recoil protons were detected using the ESPRI Recoil Proton Spectrometer (MWDC, plastic scintillator and NaI(Tl) rods) in a two-arm configuration, covering an angular range of 50°-70°. For detection of alpha clusters, two telescopes composed of silicon strip detectors and CsI(Tl) modules were placed at forward angles. Experimental results concerning missing mass spectra and triple differential cross-sections will be presented. The latter will be compared to calculations using a microscopic description of the reactions of interest implemented in the distorted wave impulse approximation, allowing to probe the alpha cluster structures directly and quantitatively. References: [1] K. Ikeda, N. Takigawa, and H. Horiuchi, Prog. Theor, Phys. Suppl. Extra Number, 464 (1968). [2] Y. Kanada-En'yo and H. Horiuchi, Phys. Rev. C 68, 014319 (2003).

[182] Interplay of different reaction channels in nuclear direct reactions with halo nuclei (10:00)

Presenter: MOSCHINI, Laura

Direct reactions of weakly-bound nuclei involve the interplay of different channels: elastic and inelastic scattering, transfer, and breakup. An effective theoretical description of such processes has to take into account the continuum [1]. Time-dependent approaches are often used to disentangle the reaction mechanism [2-3], so in Ref. [4] a simple model, that assumes semiclassical relative motion and neglects angular coordinates, was used to understand how the continuum impacts on direct reactions with one-neutron halo nuclei. In particular, a coupled-channels solution involving different continuum configurations was compared to the numerical solution of the time dependent Schrödinger equation (TDSE). The use of sets of continuum states which are sensible to the phase shift induced by only one nucleus was found not to be very accurate in the case of dominant breakup channel. Therefore, we have extended this simple time-dependent framework to include a two center "molecular" description of the continuum [5]. This consists of a set of dicretized states that reflects the phase shift induced by both nuclei involved in the process and varies with the internuclear distance [6-8]. This constitutes an improvement respect to the previous technique, not only for the good agreement with the TDSE, but also because we are able to follow the interplay of the reaction channels at each moment, thanks to the unitarity of the time-evolution operator throughout the entire process. We will report on the good outcomes of our calculations which push our investigation towards the refinement of the molecular continuum basis. We are currently working on the extension of this model to the three-dimensional space and full quantum mechanical description of the dynamics. [1] N. Austern, Y. Iseri, M. Kamimura, M. Kawai, G. Rawitscher, M. Yahiro, Phys. Rep. 154, 125 (1987) [2] B. Milek, R. Reif, J. Révai, Phys. Lett. B 150, 65 (1985) [3] M. Boselli, A. Diaz-Torres, Phys. Rev. C 92, 044610 (2015) [4] L. Moschini, A. M. Moro, A. Vitturi, Phys. Rev. C 103, 014604 (2021) [5] L. Moschini, A. Diaz-Torres, Phys. Lett. B 820, 136513 (2021) [6] B. Milek, R. Reif, Phys. Lett. B 157, 134–138 (1985) [7] G. Nuhn, W. Scheid, J. Y. Park, Phys. Rev. C 35, 2146–2155 (1987) [8] A. Diaz-Torres, W. Scheid, Nucl. Phys. A 757, 373–389 (2005)

[231] single-nucleon transfer reactions of 13B (10:20)

Presenter: LOU, jianling

We presented new experimental results of the single-nucleon transfer reactions using the radioactive beam 13B at an incident energy of 23.5 MeV/u. We extracted the p-, s- and d-wave spectroscopic factors of the 1H(13B,d) reaction to the known 12B states by comparing the deuteron angular distributions with the DWBA calculation results. The separated s- and d-wave intruder strengths in the ground state of 13B were determined to be 5(2)% and 12(2)%, respectively, which follow roughly the systematics for the N = 8 neutron-rich isotones and shell model calculations with YSOX interaction. The sudden change of the intruder sd-wave intensity between 13B and 12Be needs further theoretical interpretation[1]. We investigated the low-lying positive-parity states in 12Be, which are populated by the 2H(13B,3He) reaction via l = 1 proton transfer for the first time. Spectroscopic factors and excitation energies of these states are in reasonable agreement with the shell model predictions. Besides two bound states, we observe a resonant state at Ex = 4.8 +- 0.1 MeV with an intrinsic width of 0.42 +- 0.28 MeV, which predominately decays via one neutron to the bound states in 12Be. It most likely corresponds to the En = 1.24 MeV state observed in the previous one-proton removal reaction. The spin-parity of 2+ is tentatively assigned to this resonance according to the analysis of its angular distributions as well as the theoretical calculations, including shell model and Gamow coupled-channel approach[2]. References: [1] W.Lou, J.L.Lou* et al., Phys. Rev. C 104, 064605 (2021). [2] W.Lou, J.L.Lou* et al., Phys. Rev. C , accepted, 2022.

Coffee Break - Facultad de Ciencias de la Comunicación (10:40 - 11:20)

TUE2 - Facultad de Ciencias de la Comunicación (11:20 - 13:00)

-Conveners: Rituparna Kanungo

[269] Structure of 17B from quasi-free (p,pn) reaction (11:20)

Presenter: YANG, Zaihong

Nuclear physics has been largely extended to the vicinity of the neutron drip line (the limit of stability) in recent decades where many new intriguing phenomena have been observed. Of particular interest are nuclei with a 2n-halo structure, which generally exhibit a Borromean character without any bound binary subsystems [1]. We have carried out a measurement [2] on the structure of the 2n-halo nucleus 17B by using quasi-free (p,pn) reaction at RIBF of RIKEN Nishina Center. After the (p,pn) reaction on the vertex-tracking liquid hydrogen target MINOS [2], the charged fragments were analyzed by the SAMURAI spectrometer [3] and the neutrons were detected by the NEBULA array. A recoil proton detector array RPD, a recoil neutron detector array WINDS, and a gamma-ray detector array DALI2 were also introduced at the target region. Our result (recently published in [4]) reveals a surprisingly small s-wave component (~9%) in 17B, which is the smallest among known nuclei exhibiting halo features. In this talk, the results of the experiment will be discussed. [1] I. Tanihata, et al., Prog. Part. Nucl. Phys. 68 (2013) 215. [2] A. Obertelli, et al., Eur. Phys. J. A 50 (2014) 8. [3] T. Kobayashi, et al., Nucl. Instr. Methods B 317 (2013) 294. [4] Z. H.Yang, et al., Phys. Rev. Lett. 126, 082501 (2021).

[196] Magicity of N=32 in neutron-rich Calcium isotopes studied via (p,pn) reaction (11:40)

Presenter: ENCIU, Madalina

In nuclei far from stability, close to the neutron dripline, shell evolution is known to give rise to intricate nuclear structure, new magic numbers and halo nuclei. The formation of a new sub-shell closure at N = 32 in the neutron-rich pf-shell nuclei was reported based on a series of observations relying on E(2+) systematics, transition probability and mass measurements. Charge radii measurements show a linear increase after N = 28 in the Calcium-chain region [1,2], which were interpreted to challenge the magic character of N = 32. Recent theoretical calculations [3] suggest that halo-like p$_{3/2}$ and p$_{1/2}$ neutron orbitals, with the size $\sim$0.7fm larger than f$_{7/2}$ in this neutron-rich region, could explain the observed behavior in the charge radii measurements. I will present in this talk one neutron-knockout reaction measurements performed on ^{52}Ca in inverse kinematics at $\sim$260 MeV/u beam energy on a 151-mm-long liquid hydrogen target at the RIBF facility. A systematic comparison of neutron-removal cross-sections from orbitals below and above shell closure, between ^{52}Ca and the well-established doubly-magic Ca-isotopes, ^{48}Ca and ^{54}Ca, corroborate the magicity of N = 32. In addition, the extracted rms of the p$_{3/2}$ and f$_{7/2}$ single-particle orbitals from the measured momentum distributions in ^{52}Ca(p,pn) reaction is in line with the theoretical calculations and supports the halo nature of the p$_{3/2}$ neutron orbital. To summarize, our results provide direct evidence for the N = 32 subshell closure and are in agreement with a 'huge' p$_{3/2}$ neutron orbital and the increased charge radius of ^{52}Ca. [1] Koszorús, Á., Yang, X.F., Jiang, W.G. et al. Charge radii of exotic potassium isotopes challenge nuclear theory and the magic character of N=32. Nat. Phys. 17, 439–443 (2021) [2] Garcia Ruiz, R., Bissell, M., Blaum, K. et al. Unexpectedly large charge radii of neutron-rich calcium isotopes. Nature Phys 12, 594–598 (2016) [3] J. Bonnard, S.M. Lenzi, and A.P. Zuker. Neutron Skins and Halo Orbits in the sd and pf Shells. Phys. Rev. Lett. 116, 212501 (2016)

[284] 12C(p,2p)11B Quasi-Free-Scattering in Inverse Kinematics at R^{3}B; For the R3B Collaboration (12:00)

Presenter: JENEGGER, Tobias

The advanced R^{3}B setup at GSI allows to investigate proton-induced-quasi-free one-nucleon knockout reactions of exotic nuclei in inverse kinematics. This technique gives direct access to the momentum distributions of the scattered off protons in the nucleus before as well as the recoil momentum of the remaining spectator nucleus. In addition to the correlated gamma spectrum it is a powerful tool to unveil individual states populated in the reaction. The CALIFA calorimeter, with its 2528 CsI scintillation crystals in its final design, is a key detector in quasi-free-scattering experiments at R^{3}B. Covering the full azimuthal range and having a polar angular acceptance from 22° up to 89° in the target region already now it allows to detect both the two coincident protons from the quasi-free-scattering process and emitted γ-rays from de-excitation of the remaining nucleus with high angular resolution and precise Doppler correction. For the heavy residues unique particle identification was performed with multi-sampling ionization chambers and a high resolution tracking system before and after the GLAD magnet, resulting in a relative mass resolution of less than 0.5 percent. We present first results from the S444 experiment performed in the FAIR Phase-0 campaign in February 2020 with relativistic 12C beams at various energies and CH2 targets focusing on the angular correlations of the quasi-free-scattered protons, the nucleons initial momentum reconstruction and the associated gamma ray spectra. Results presented here are based on the experiment S444, which was performed at the R3B Experiment at the GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt (Germany) in the context of FAIR-Phase-0. Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy EXC-2094-390783311 and Bundesministerium für Bildung und Forschung,BMBF-05P19WOFN1 – 05P21WOFN1.

[230] Studies of quasi-free proton knockout reactions with the CALIFA Calorimeter at the R3B/FAIR Setup (12:20)

Presenter: ATAR, Leyla

A successful and widely used tool for the understanding of the single-particle structure and the role of nucleon-nucleon correlations is proton-induced quasi-free scattering reactions (QFS) at relativistic energies. This technique was successfully applied at the R3B/LAND setup (at GSI in Germany) and has been used with an upgraded setup for the future R3B program at FAIR/GSI. One of the key detectors of the R3B setup is CALIFA (the CALorimeter for In Flight detection of gamma-rays and light charged pArticles) to detect the knocked-out nucleon as well as the recoiled target proton originating from a QFS reaction. CALIFA is highly segmented and currently consist of 1528 scintillation CsI(Tl) crystals to facilitate measurement of the emission angle and energy of reaction products. CALIFA covers a large dynamic range to allow a coincidence measurement of γ-rays down to 100 keV and scattered protons up to 700 MeV. A special feature of Califa is the digital Quick Particle Identification (QPID) enabling gamma and charged particle identification through Pulse Shape Analysis (PSA) of the scintillation light output. The QFS signature has been observed by angular correlations of the knocked-out nucleon and recoiled target proton. The high crystal granularity and large angular coverage of CALIFA allow to obtain angular correlations between the scattered particles with an angular resolution and a high detection efficiency. The γ-rays emerging from the excited nuclei are also measured with very high efficiency and a precise Doppler correction. We present results from selected (p,2p) reactions in the frame of FAIR Phase-0 experiments. The discussion will include angular correlation of (p,2p) events and simultaneous measurement of γ-rays of the final bound states of the residual nuclei as well as QPID application to select (p,2p) protons for specific physics cases. It will be followed by a discussion of a benchmark (p,2p) experiment on a heavy nuclei 208Pb as a proof of concept. The conducted experiment is the first successful measurement of a (p,2pγ) reaction for such heavy nuclei and hence a good test case for experiments planned at R3B/FAIR to investigate third r-process peak. The preliminary results will be presented and measured γ-ray spectra will be compared to the existing data in literature. This work is supported by the German Federal Ministry for Education and Research (BMBF projects 05P19RDFN1, 05P21RDFN2 and 05P19RWOFN1) and the FAIR Phase-0 experimental program.

[228] The (p,3p) two-proton removal from neutron-rich nuclei (12:40)

Presenter: FROTSCHER, Axel

The knockout of nucleons from nuclei is a powerful tool to investigate nuclear structure. It was observed in several occurrences that different final states in a nucleus are populated when produced from one nucleon knockout *(p,2p)* or from two nucleon knockout *(p,3p)*. The understanding of the latter could provide a new tool for nuclear spectroscopy. Two experimental campaigns conducted at the RIBF in RIKEN, Japan, were investigated. The scattered proton angular distribution from several neutron-rich medium-mass nuclei were analysed. The radioactive nuclei were impinging onto a 100-mm long liquid hydrogen target. The protons issued from the reaction were measured with the MINOS time-projection chamber surrounding the target, giving access for the first time to angular correlations of the three protons in the final state. The obtained proton distributions were benchmarked against kinematical models assuming three different reaction mechanisms.

Lunch Break - Facultad de Ciencias de la Comunicación (13:00 - 14:40)

TUE3 - Facultad de Ciencias de la Comunicación (14:40 - 16:20)

-Conveners: Dolores Cortina

[288] Scattering of ^{15}C on ^{208}Pb at energies near the Coulomb barrier (14:40)

Presenters: GARCIA BORGE, Maria Jose, GARCIA TAVORA, Vicente

documentclass[article]{revtex4-2} \bibliographystyle{apsrev4-2} % Remove any % below to load the required packages \usepackage{latexsym} \usepackage{graphicx} \usepackage{amsmath} \usepackage{rotating} \usepackage{hyperref} \usepackage{xcolor,colortbl} \usepackage[utf8]{inputenc} \usepackage{xcolor} \usepackage{multirow} \usepackage{graphicx}% Include figure files \usepackage{dcolumn}% Align table columns on decimal point \usepackage{bm}% bold math \usepackage[columnwise]{lineno} % para numerar las lineas \usepackage{setspace} % para modificar el espacio entre lineas \newenvironment{rotatepage}% {\clearpage\pagebreak[4]\global\pdfpageattr\expandafter{\the\pdfpageattr/Rotate 90}}% {\clearpage\pagebreak[4]\global\pdfpageattr\expandafter{\the\pdfpageattr/Rotate 0}}% \renewcommand{\arraystretch}{1.5} \begin{document} \title{Scattering of ^{15}C on ^{208}Pb at energies near the Coulomb barrier} \author{J.D. Ovejas} \affiliation{Instituto de Estructura de la Materia, CSIC, Serrano 113-bis, E-28006 Madrid, Spain} \author{V.G. Tavora} \affiliation{Instituto de Estructura de la Materia, CSIC, Serrano 113-bis, E-28006 Madrid, Spain} \author{I. Martel} \affiliation{Departamento de F\'isica Aplicada, Universidad de Huelva, E-21071, Huelva, Spain} \author{A.M. S\'anchez-Ben\'iÂtez } \affiliation{Departamento de F\'isica Aplicada, Universidad de Huelva, E-21071, Huelva, Spain} \author{O. Tengblad} \affiliation{Instituto de Estructura de la Materia, CSIC, Serrano 113-bis, E-28006 Madrid, Spain} \author{M.J.G. Borge} \affiliation{Instituto de Estructura de la Materia, CSIC, Serrano 113-bis, E-28006 Madrid, Spain} \author{A. Di Pietro} \affiliation{INFN, Laboratori Nazionali del Sud, via S. Sofia 62, 1-95123, Catania, Italy} \author{P. Figuera} \affiliation{INFN, Laboratori Nazionali del Sud, via S. Sofia 62, 1-95123, Catania, Italy} \author{N. Keeley} \affiliation{National Center for Nuclear Research, ul Andrzeja Soltana 7, 05-400 Otwock, Poland} \author{K. Rusek} \affiliation{National Center for Nuclear Research, ul Andrzeja Soltana 7, 05-400 Otwock, Poland} \maketitle Nuclear systems such as ^{6}He, ^{11}Li, ^{11}Be, ^{14}Be are known to have extended neutron distributions: the so-called neutron halos~\cite{Tan85,Rii13}. This feature occurs when the separation energy of valence neutrons is much smaller than the average binding energy per nucleon in a nucleus, so they can tunnel out of the nuclear potential to large distances with sizable probability. It has been an intense experimental and theoretical activity dedicated to study the existence of halos and their dynamics in reaction processes. The neutron halo produces a pronounced maxima at low excitation energies in the Coulomb dipole strength B(E1), very narrow transverse momentum distributions and large interaction cross-sections when measured at high energies~\cite{Aum05}. The dynamics of the halo nuclei scattering at low energies, around the Coulomb barrier, is dominated by the coupling between the elastic channel and collective excitations, neutron transfer and breakup. The angular distributions of the elastic cross section and the core fragments present large sensitivity to these coupling effects, which are due to the halo configuration. This has been demonstrated by us in previous studies with light exotic beams of ^{6}He, ^{11}Li and ^{11}Be scattered on heavy targets~\cite{San08,Cub12,Pes17}. The angular distribution of the elastic channels shows strong absorption patterns where the nuclear and Coulomb interference completely disappears. The ^{15}C nucleus (T$_{1/2}$ = 2.449(5) s) has a low single-neutron separation energy S$_n$=1218.1(8) keV in comparison with the two-neutron separation energy S$_{2n}$=9394.5(8) keV~\cite{Wan12}. The spins and parities of the ground and first excited state at E= 740 keV are known to be I$^{\pi}$=1/2$^+$, 5/2$^+$, respectively. The halo structure of ^{15}C has been investigated at relatively high energies in several experiments. The reaction cross section at high energy (83 MeV/u) shows an enhancement respect to the neighboring ^{14,16}C isotopes and the longitudinal momenta of the ^{14}C fragments after 1n-breakup present a FWHM distribution between 64-70 MeV/c depending of the target~\cite{Baz98,Sau00,Fan04} that it is narrower than that of the neighbour ^{14,16}C isotopes, $\approx$ 200 MeV/c, but wider than the $\approx$ 40-50 MeV/c found for the archetype cases~\cite{Aum05}. These properties have hinted the presence of a halo configuration in the ^{15}C nucleus that would be unique in the sense that it can be described with an almost pure s$_{1/2}$ ground state wavefunction. To complete our understanding of the role of the halo in ^{15}C, we have studied its dynamical response at energies close to the Coulomb barrier that has not been yet probed until this work. We studied the scattering of 4.37 MeV/u ^{15}C beam on a lead target at HIE-ISOLDE, CERN using the GLORIA setup~\cite{Mar14}. In this contribution we will present the angular distribution of the elastic cross section of ^{15}C + ^{208}Pb. Optical Model calculations properly describe the angular distribution of the elastic channel and indicate an enhancement of the total reaction cross section. \begin{thebibliography}{999} \bibitem{Tan85} I. Tanihata \textit{et al.}, Phys. Rev. Lett. {\bf 55}, 24 2676 (1985). \bibitem{Rii13} K. Riisager, Phys. Scr. {\bf T152}, 014001 (2013). \bibitem{Aum05} T. Aumann, Eur. Phys. J. A {\bf 26}, 441 (2005). \bibitem{San08} A.M. S\'anchez-Ben\'iÂtez \textit{et al.}, Nuclear Physics A {\bf 803}, 30 (2008). \bibitem{Cub12} M. Cubero \textit{et al.}, Phys. Rev. Lett. {\bf 109}, 262701 (2012). \bibitem{Pes17} V. Pesudo \textit{et al.}, Phys. Rev. Lett. {\bf 118}, 152502 (2017). \bibitem{Wan12} M. Wang \textit{et al.}, Chin. Phys. C {\bf 36}, 1603 (2012). \bibitem{Baz98} D. Bazin \textit{et al.}, Phys. Rev. C {\bf 57}, 2156 (1998). \bibitem{Sau00} E. Sauvan \textit{et al.}, Phys Lett B {\bf 491}, 1 (2000). \bibitem{Fan04} D.Q. Fang \textit{et al.}, Phys. Rev. C {\bf 69} 034613 (2004). \bibitem{Mar14} G. Marqu\'inez-Dur\'an \textit{et al.}, Nuc. Inst. and Methods in Phys. Res. A {\bf 755} 69 (2014). \end{thebibliography} \end{document}

[278] Gamow-Teller Giant Resonance in 11Li neutron drip-line nucleus (15:00)

Presenter: STUHL, László

We started a program [1] at the RIKEN Radioactive Isotope Beam Factory (RIBF) aiming to measure the spin-isospin responses of light nuclei along the neutron drip line. There is no available data on spin-isospin collectivity for nuclei with large isospin asymmetry factors, where (N−Z)/A>0.25 [2]. We investigated this unexplored region up to (N−Z)/A=0.5. The spin-isospin responses of ^{11}Li and ^{14}Be drip-line nuclei were measured in charge-exchange (p,n) reactions at around 180 MeV/nucleon beam energies. These reactions in inverse kinematics, at intermediate beam energies (E/A>100 MeV) and small scattering angles can excite Gamow-Teller (GT) states up to high excitation energies in the final nucleus, without Q-value limitation [3,4]. The combined setup [5] of our new, digital-readout-based low-energy neutron spectrometer, PANDORA (Particle Analyzer Neutron Detector Of Real-time Acquisition) [6] and the SAMURAI large-acceptance magnetic spectrometer [7] together with a thick liquid hydrogen target allowed us to perform the SAMURAI30 experiment with high luminosity. In this setup, PANDORA was used for the detection of the recoil neutrons with kinetic energy of 0.1–5 MeV, while the SAMURAI was used for tagging the decay channels of the reaction residues. It was proven, in our first (p,n) experiment on ^{132}Sn [8], that using such setup we can take data on unstable nuclei with quality comparable to those on stable nuclei. In this talk, details of experimental setup as well as the intelligent digital-pulse processing for neutron-gamma discrimination with PANDORA will be presented. We successfully identified 15 different decay channels of the ^{11}Be reaction product. Preliminary result of the reconstructed excitation-energy spectrum and B(GT) distribution up to 40 MeV, including the Gamow-Teller (GT) Giant Resonance region in ^{11}Li, will be reported. Our observation, that GT peak occurs below the Isobaric Analog State in ^{11}Li, will be discussed in connection with the variation of residual spin-isospin interaction in exotic nuclei. [1] L. Stuhl et al., RIKEN Accelerator Progress Report 48, 54 (2015). [2] K. Nakayama, et al., Phys. Lett. B 114, 217 (1982). [3] M. Sasano et al., Phys. Rev. Lett. 107, 202501 (2011). [4] M. Sasano et al., Phys. Rev. C 86, 034324 (2012). [5] L. Stuhl et al., Nucl. Instr. Meth. B 463, 189 (2020). [6] L. Stuhl et al., Nucl. Instr. Meth. A 866, 164 (2017). [7] T. Kobayashi, et al., Nucl. Instr. Meth. B 317 294 (2013). [8] J. Yasuda et al., Phys. Rev. Lett. 121, 132501 (2018).

[263] Consistent description for 11Li scattering from light to heavy targets (15:20)

Presenter: RODRÍGUEZ-GALLARDO, Manuela

The Borromean nucleus ^{11}Li presents a two-neutron halo structure that still hides a lot of information about it. Several experimental and theoretical works have tried to shed light in its structure and reaction dynamics during the past decade [Phys. Rev. Lett 109 (2012) 262701; 110 (2013) 142701; 114 (2015) 192502; Phys. Lett. B 774 (2017) 268; Phys. Rev. C 85 (2012) 054610; 92 (2015) 044608; 101 (2020) 064611; Prog. Theor. Exp. Phys. (2019) 123D02]. The existence of a dipole resonance, its character and its position in energy is under discussion. We present here a consistent description of reactions induced by 11Li on different targets, including ^{208}Pb, protons and deuterons, within the same four-body formalism. The continuum-discretized coupled-channels method [Phys. Rev. C 77 (2008) 064609; 80 (2009) 051601(R)] is used with the same structure model for all the reactions. This model provides a dipole resonance at about 0.70 MeV over the ground state. The results for alternative positions for this resonance will be also discussed.

[191] Investigation of dineutron correlations at the surface of Borromean nuclei (15:40)

Presenter: CASAL, Jesús

The correlation among the valence neutrons in Borromean halo nuclei are a key element to explain the stability of such loosely bound systems [1,2]. The characterization of the dineutron correlation is therefore an important step in the description of the neutron dripline. We present here a comparative study of three different two-neutron halos, ^{11}Li, ^{14}Be and ^{17}B, simultaneously studied in a quasi-free scattering experiment performed at the RIBF facility in RIKEN. For the three nuclei, data suggest dineutron correlation always appears at low intrinsic momenta. This constitutes the first experimental proof of the universality of the dineutron correlation in the low-density nuclear surface of Borromean nuclei, which had been previously suggested [3-6]. Overall, a progressive damping of the dineutron correlation going from ^{11}Li to ^{17}B is observed. The experimental results are compared to calculations based on a three body model for the structure and a quasi-free sudden model for the reaction [7,8]. The structure inputs for ^{11}Li ($^9\text{Li}+n+n$) and ^{14}Be ($^{12}\text{Be}+n+n$) are based on previous (p,pn) calculations [9,10]. The former includes the splitting due to the finite spin of the ^{9}Li core, and the latter incorporates further the excitation to the first 2$^+$ state of ^{12}Be. For ^{17}B ($^{15}\text{B}+n+n$), a simple model is built to reproduce the main features observed in a recent experiment [11], which points towards dominance of d-waves. In all cases, the dineutron correlation appears due to mixing between different-parity components, even if small. The maximum correlation angle corresponds in all cases to the same intrinsic momentum region, in agreement with the data. For ^{14}Be, calculations suggest that, in spite of the large mixing in the model, core excitations diminish the dineutron correlations noticeably. These results pave the path for future studies on the correlations in heavier dripline nuclei. [1] M. V. Zhukov et al., Phys. Rep. 231, 151 (1993). [2] K. Hagino and H. Sagawa, Phys. Rev. C 72, 044321 (2005). [3] A. B. Migdal, Yad. Fiz. 16, 427 (1972). [4] M. Matsuo, Phys. Rev. C 73, 044309 (2006). [5] K. Hagino, H. Sagawa, J. Carbonell and P. Schuck, Phys. Rev. Lett. 99, 022506 (2007). [6] Y. Kubota et al., Phys. Rev. Lett. 125, 252501 (2020). [7] J. Casal and M. Go´mez-Ramos, Phys. Rev. C 104, 024618 (2021). [8] Y. Kikuchi et al., Prog. Theor. Exp. Phys., 2016, 103D03 (2016). [9] M. Go´mez-Ramos, J. Casal and A. M. Moro, Phys. Lett. B 772, 115 (2017). [10] A. Corsi et al., Phys. Lett. B 797, 134843 (2019). [11] Z. H. Yang et al., Phys. Rev. Lett. 126, 082501 (2021).

[202] Direct measurement of the 22Mg(alpha,p)25Al reaction using MUSIC relevant for Type I X-ray bursts (16:00)

Presenter: JAYATISSA, Heshani

The dominant (p,γ) nucleosynthesis flow in Type I X-ray bursts (XRBs) is halted at several waiting point nuclei such as ^{22}Mg, $^{24-26}$Si, $^{28-30}$S and ^{34}Ar due to (p,γ)-(γ,p) equilibrium. Reactions such as (α,p) reactions assist the nucleosynthesis flow to bypass these waiting points. The present uncertainties in the relevant (α,p) reaction rates at these waiting points hinder the ability to accurately predict the light curve and ash composition of XRBs. For these waiting point nuclei, the ^{22}Mg(α,p)^{25}Al reaction has been identified as an important reaction bypassing the waiting points for XRB nucleosynthesis. Thus, it is crucial to constrain the reaction rate of the ^{22}Mg(α,p)^{25}Al reaction at astrophysical energies. To this end, we have performed a direct measurement of the ^{22}Mg(α,p)^{25}Al reaction cross section in inverse kinematics using a ^{22}Mg beam from the Argonne In-Flight Radioactive Ion Separator (RAISOR) and the MUlti-Sampling Ionization Chamber (MUSIC) at Argonne National Laboratory. Preliminary results from this measurement will be discussed.

Poster session - Facultad de Ciencias de la Comunicación (16:20 - 18:00)

[254] Cross sections of neutron-rich isotopes near N=50 in knock-out reactions (16:20)

Presenter: FRANCHOO, Serge

We present cross sections for neutron-rich copper (Z=29) to germanium (Z=32) isotopes in nucleon-removal reactions. The experiments were carried out at the Radioactive Isotope Beam Factory of the Riken laboratory during the Seastar campaign, where an incident beam of 238U at 345 MeV/u created a range of exotic nuclei in a beryllium target. These nuclei were sent through the Bigrips separator onto the Minos cryogenic hydrogen target, in which secondary reactions took place. The outcoming fragments were subsequently identified in the Zerodegree separator. Our results are in agreement with our previous study [1] regarding the dependence of the proton knock-out cross section on the nucleon separation energy. For knock-out reactions of a single neutron, we find that the cross section reaches its highest value for projectiles with the magic neutron number N = 50, after which it drops sharply. This reflects the occupancy of the valence orbital and conforms to eikonal predictions [2], whilst departing from the flat trend that was noted in our earlier publication [1]. 1. N. Paul et al., Physical Review Letters 122, 162503 (2019) 2. T. Aumann, C. Bertulani, and J. Ryckebusch, Physical Review C 88, 064610 (2013)

[252] Effects of pairing through the intermediary continuum in a 2n transfer process (16:25)

Presenter: SINGH, Gagandeep

Two particle transfer reactions provide realistic tools to understand reaction mechanisms due to the enhanced matrix elements connecting systems of neighbouring nuclei differing by two units. The resultant pairing interactions in the (A+2) nuclei, if present in a weakly bound system near the drip lines, can develop diffused Borromean halos as the Cooper pair of the nucleons can scatter into the continuum states of the intermediary nucleus [1]. The ^{6}He nucleus presents a perfect candidate to study such pairing effects in a diffused halo near the neutron drip line. In fact, apart from the nuclear physics viewpoint, an understanding of 6He structure is also crucial due to its vital role in stellar astrophysics [2]. We, therefore, perform two neutron transfer calculations for the reaction ^{18}O(^{4}He,^{6}He)^{16}O using a modified version of the Transformed Form Factors (TFF) code [3]. We generate the spectra of the intermediary ^{5}He via the pseudostates (PS) approach, for which we use the analytical transformed harmonic oscillator (THO) basis [4]. THO maintains the lucidity of the harmonic oscillator functions, converting, however, their

Gaussian asymptotic behavior to a better suited exponential mode [4]. We differentiate three cases of interest on the basis of the ground state of ^{5}He. In the two hypothetical cases, it is bound with one neutron separation energies S_n of 1 and 0.1 MeV. For the realistic case, a state in our discretized continuum (at 0.69 MeV) represents the resonance at 0.79 MeV. Our results indicate that pairing enhancement is largest for the continuum case and can significantly enhance the two neutron transfer cross-sections in the cases when the intermediary nucleus does not have a bound state. This provides a way to study the formation of Borromean halos near the neutron drip line in the light mass region. References [1] W. von Oertzen and A. Vitturi, Reports on Progress in Physics 64, 1247 (2001). [2] A. Bartlett, J. G orres, G. J. Mathews, K. Otsuki, M. Wiescher, D. Frekers, A. Mengoni, and J. Tostevin, Phys. Rev. C 74, 015802 (2006). [3] L. Fortunato, I. Inci, J.-A. Lay, and A. Vitturi, Computation 5(3), 36 (2017). [4] J. Casal, M. Rodr□□guez-Gallardo, and J. M. Arias, Phys. Rev. C 88, 014327 (2013); J. A. Lay, A. M. Moro, J. M. Arias, and J. G omez-Camacho, Phys. Rev. C 85, 054618 (2012).

[239] Measurement of the single-particle strength along the calcium isotopic chain using quasi-free scattering reactions (16:30)

Presenter: TANIUCHI, Ryo

Several properties of atomic nuclei are known to be sensitive to the neutron-to-proton (isospin) asymmetry. Isotopic chains that extend from the valley of beta-stability towards the drip lines have now become accessible with the advent of radioactive-ion beam facilities. In particular, the evolution of the single-particle strength as a function of isospin has been the subject of experimental and theoretical debate. Quasi-free scattering reaction is an established method to probe the structure of atomic nuclei. Employing this reaction in inverse kinematics using radioactive-ion beams at relativistic energies is proving an effective tool to study very exotic nuclei with high luminosity. Recent studies [1, 2] reported on the evolution of the proton single-particle strength with isospin asymmetry using (*p,2p*) quasi-free reactions along the Oxygen isotopic chain and found a weak or no dependence of the single-particle strength with isospin. This contrasts with nucleon-removal reactions [3, 4] where they report a reduction factor that is strongly correlated with isospin. The reduction of the single-particle strength has been attributed to nucleon-nucleon correlations and a recent phenomenological study [5] has attempted to quantify the long and short-range part of these correlations and their dependency with isospin. To shed light on this puzzle, we performed a systematic study of (*p,2p*) cross sections along the calcium isotopic chain (from ^{38}Ca to ^{51}Ca) at 500 MeV/nucleon. The experiment was performed with the R3B setup at GSI-FAIR. Preliminary results of the analysis will be discussed in this contribution. [1] L. Atar et al., Phys. Rev. Lett. 120, 52501 (2018). [2] Shoichiro Kawase et al., Prog. Theor. Exp. Phys. 2018, 021D01. [3] A. Gade et al., Phys. Rev. C 77, 044306 (2008). [4] J. A. Tostevin and A. Gade, Phys. Rev. C 90, 057602 (2014). [5] S. Paschalis, M. Petri, A. O. Macchiavelli, O. Hen, E. Piasetzky, Phys. Lett. B 800, 135110 (2020).

[245] First results of the analysis of the reaction 22 Mg(α,α) 22 Mg (16:35)

Presenter: REGUEIRA CASTRO, Daniel

In this work, I will present the preliminary results of the study of the resonance states in 26 S by elastic scattering of 22 Mg(α,α) 22 Mg. Resonances in 26 S are important to determine the reaction rate of the 22 Mg(α,p) 25 Al [1] and 25 Al(p,γ) 26 Si. The study of the resonances was performed using the active target ATTPC [2] with a re-accelerated radioactive beam produced in the ReA3 installation at NSCL (USA).A beam of 22 Mg at around 4.9 MeV/u impinged in the 4 He gaz volume in ATTPC. Information on the Bρ, and angle was used to deduce the excitation energy function in 26 Si. Referencies [1] Randhawa, Jaspreet Singh et al., Physical Review Letters, 125, (2020). [2] Y.Ayyad et al., Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 954, 161341, (2020) .

[248] Investigating Short-Range Correlations in exotic nuclei at R3B using inverse kinematics (16:40)

Presenter: LORENZ, Enis

Short-Range Correlations (SRC) are two-body components of the nuclear wave function with high relative momentum and low center-of-mass momentum relative to the Fermi momentum, k$_F$. These high-momentum nucleons, which are absent in a simple Fermi gas model, are formed as temporary closed-proximity nucleon pairs with high density, several times the nuclear saturation density. Studying the characteristics of SRC-pairs gives an unique opportunity to explore the interaction of cold dense nuclear matter as in neutron stars. The first kinematically complete measurement of SRC in exotic nuclei will be performed at the R^{3}B setup as part of the FAIR Phase-0 experimental program in Spring 2022 by scattering a ^{16}C beam off a liquid hydrogen target in inverse kinematics at energy of 1.25 GeV/nucleon. This work is supported by the State of Hesse within the Research Cluster ELEMENTS project 500/10.006 and by the German Federal Ministry for Education and Research (BMBF) under contract number 05P21RDFN2.

[249] Study of multi-nucleon knockout reactions of exotic nuclei in the region of Sn (16:45)

Presenter: FEIJOO FONTÁN, Martina

The experimental data collected during the S515 experiment performed by R3B collaboration at GSI/FAIR represent a great opportunity to obtain nucleon knockout cross sections of exotic nuclei around 132Sn. These cross sections can be used to extract information about short-range correlations (SRCs), which emerge from pairs of nucleons having large relative momentum compared to their centre-of-mass momentum [1]. Recently, several works based on inclusive measurements [2,3] have shown that these SRCs could reduce the single nucleon knockout cross sections by around 50%, depending on the neutron excess (N/Z) of the initial projectile. The S515 data could help us to go further in this investigation because we could correlate the knockout cross sections of one and two nucleons with the number of protons and neutrons detected by CALIFA and NeuLAND and perform complete kinematical studies to separate between SRC events and others involving evaporation of particles. At the moment, the identification of the fragments between FRS and Cave C is done for the 124Sn settings (136Xe fragmentation), as well as charge calibrations for the LOS and R3B-MUSIC detectors and energy calibration for CALIFA crystals. Thus, the resulting yields for different incoming energies and targets can be compared. [1] M. Duer et al., Nature 560 620 (2018) [2] J. Díaz-Cortés et al., Physics Letters B 811 (2020) 135962 [3] V. Vaquero et al., Physics Letters B 795 (2019) 356

[250] Quasi-free (p,2p) reactions in inverse kinematics for studying the fission yield dependence on temperature and its implication in the stellar nucleosynthesis r-process (16:50)

Presenter: GRAÑA GONZÁLEZ, antía

Although the importance of the fission fragment treatment in stellar nucleosynthesis r-process calculations is well established, an aspect of the phenomenological descriptions of fission that has so far remained relatively unexplored in the r-process is the dependence of the fission yields on the excitation energy or temperature of the compound nuclei [1]. Moreover, the fission yields and fission barrier heights of nuclei far from the stability line are also crucial to correctly describe the r-process cycle as well as the transitions from symmetric to asymmetric fission [2]. To determine all these observables, we have carried out at the GSI facility a new experiment in inverse kinematics and using quasi-free (p,2p) reactions as a novel technique to induce the fission process [3]. These new measurements have been performed with state-of-the art detectors especially designed to measure the fission products with high detection efficiency and acceptance, which were developed by the R3B collaboration [4]. The analysis of this new data will give us for the first time access to the excitation energy of the fissioning system by using the missing mass method and thus it will allow us to investigate the evolution of fission yields with the temperature. [1] N. Vassh et al., J. Phys. G: Nucl. Part. Phys. 46, 065202 (2019) [2] T. Kajino et al., Prog. Part. Nucl. Phys. 107, 109 (2019) [3] J. Benlliure and J.L Rodríguez-Sánchez, Eur. Phys. J. Plus 132, 120 (2017)

[190] Development and characterization of new position-sensitive Si strip detectors for direct reactions at CENS (16:55)

Presenter: PEREIRA-LOPEZ, Xesus

Direct reaction experiments in inverse kinematics are one of the best suited tools to probe a broad range of nuclear properties, providing great insight into the nuclear structure of exotic nuclei and allowing the measurement of reactions relevant to many astrophysical scenarios. In order to fully exploit RAON (RIB facility currently under construction in Korea), the CENS group has devoted a large amount of effort to develop nuclear detection instruments, such as ATOM-X Active Target TPC and STARK Silicon Telescope Array, specially designed for direct reaction experiments. An integral part of these detector devices are position-sensitive double sided silicon strip detectors. These detectors are segmented in 4 strips on its ohmic side and 8 resistive charge-splitting strips on its junction side enabling an excellent position measurement of charged particles with a much smaller number of signals than traditional DSSSD with similar position resolution. Detailed specifications of these detector devices, initial characterization methods and preliminary reports of their performance will be presented. Outlook for future commissioning of these detectors will also be discussed.

[259] Measurements of the neutron-removal cross sections of neutron-rich Sn isotopes at R3B setup. (17:00)

Presenter: KUDAIBERGENOVA, Eleonora

The equation of state (EoS) plays a key role in many different aspects of modern physics, being fundamental for understanding the structure of nuclear matter, the properties of neutron stars, core-collapse supernova explosions, and the synthesis of heavy elements. While the properties of proton-neutron symmetric matter are relatively well known, the study of asymmetric matter via properties of neutron-rich nuclei became a current focus of investigation. The asymmetry part of the nuclear EoS is expressed by the symmetry energy at saturation J and its slope L. Constraining these parameters is one of the central issues in nuclear physics, especially since the slope parameter L has not yet been constrained well experimentally. It has been identified that a precise determination of the neutron removal cross section of neutron-rich nuclei, which is directly related to the neutron skin, would provide a much better constraint on L. To this end, the experiment was performed with the neutron-rich tin isotopes in the mass range A=124-134 on carbon targets at the R3B setup at the GSI/FAIR facility in inverse kinematics with very large acceptance. The goal of which is to constrain the L parameter from the accurate measurement of the neutron removal cross section by comparison to density functional theory. This project was supported by the BMBF project No. 05P15RDFN1, the Helmholtz Research Academy Hesse for FAIR, and the GSI-TU Darmstadt cooperation.

[265] Continuum-Discretized Coupled Channel description of (d,p) reactions with nonlocal optical potentials (17:05)

Presenter: TIMOFEYUK, Natalia

Treating deuteron breakup in (d,p) reaction requires solving three-body Schrodinger equation with nucleon optical potentials. According to a general theory of optical potentials they should be nonlocal. We present two approximate methods to account for this nonlocality within the Continuum-Discretized Coupled Channel (CDCC) method: (1) we derive a leading-order local-equivalent CDCC model and (2) we solve the CDCC equations with velocity-dependent optical potentials that represent nonlocal optical potential in the next-to-leading order. Examples of numerical calculations will be given.

[266] Three-nucleon force in (d,p) reactions (17:10)

Presenter: TIMOFEYUK, Natalia

The three-nucleon (3N) force is important for understanding the structure and dynamics of atomic nuclei and nuclear matter from first principles and it is routinely used in many ab-initio structure calculations. It is also included in calculations describing reactions involving nuclei that can be modelled as few-body systems. First calculations of elastic scattering with ab-initio potentials have also been recently reported. However, 3N force is not considered in analyses of experimental data involving direct reactions with complex nuclei. One particular class of such reactions, deuteron stripping (d,p) and pick-up (p,d), is an important experimental tool for testing the shell-model picture of atomic nuclei, which is often used for indirect determination of nucleon capture reaction rates at astrophysical energies. Here, recent advances in clarifying the role of the 3N force in (d,p) reactions will be described. --

[274] Performance of the CALIFA detector during the experiment s467 on the Ca isotopic chain (17:15)

Presenter: SUERDER, Christian

In Feb. 2020 an experiment to study single particle properties around the Ca isotopic chain, reaching from the proton-rich to the neutron-rich side, was performed with the versatile R3B setup at GSI, Darmstadt, Germany. The secondary cocktail beam included neutron-rich isotopes from Cl to Cr. This experiment, part of the R3B Phase 0 program at FAIR, allowed for exclusive studies in inverse kinematics by coincident measurement of outgoing particles and gamma rays, employing reactions like (p,2p), (p,pn), etc. The knocked out particles were detected with CALIFA, a CsI detector with high granularity, situated around the target area. The poster presents performance aspects of CALIFA. Basic properties are shown, like geometry and energy resolution. A focus is on proton and gamma detection efficiency, utilizing hit reconstruction algorithms and investigating their effects on the efficiency. A (p,2p) reaction channel is picked to show the fingerprint parameters for a quasi-free scattering reaction, detected with CALIFA.

[279] Integration of a Resistive Plate Chamber for Precise Measurement of High-Momentum Protons in Short Range Correlations (17:20)

Presenter: XAREPE, Manuel

The first short-range correlation (SRC) experiment with an exotic nucleus (16C) will be performed in the Spring 2022 within the R3B collaboration as part of the FAIR Phase-0 experimental program. The study of SRC pairs at high relative momentum and low center-of-mass momentum relative to the Fermi momentum (kF) gives insight into the nucleon-nucleon interactions of cold, dense matter similar to the conditions found in neutron stars. The forward-emitted protons from the high-momentum correlated pairs will be detected using the newly implemented Resistive Plate Chamber (RPC). The time-of-flight method will be applied, taking advantage of the excellent time resolution properties of the RPC (about 50 ps). In this work, the RPC detector will be introduced, the integration of the detector in the R3B setup will be presented, and some preliminary results will be shown.

[290] Investigating cross-shell interactions at the N=28 shell closure through 47K(d,p)48K with MUGAST+AGATA+VAMOS. (17:25)

Presenter: PAXMAN, Charlie James

The region around the magic numbers $N=28$ and $Z=20$ is of great interest in nuclear structure physics. Moving away from the doubly-magic isotope ^{48}Ca, in the neutron-rich direction there is evidence of an emergent shell gap at $N=34$ [1], and in the proton-deficient direction, the onset of shape deformation suggests a weakening of the $N=28$ magic number [2]. The ^{47}K(d,p)^{48}K reaction is uniquely suited to investigating this region, as the ground state configuration of ^{47}K has an exotic proton structure, with an odd proton in the π(1s$_{1/2}$) orbital, below a fully occupied π(0d$_{3/2}$) orbital [3]. As such, the selective neutron transfer reaction (d,p) will preferentially populate states in ^{48}K arising from π(1s$_{1/2}$)$\otimes$ ν(fp) cross-shell interactions. The implications of this extend both down the proton-deficient $N = 28$ isotonic chain, where these interactions are expected to dominate the structure of the exotic, short-lived ^{44}P nucleus [4], and across the neutron-rich region, where the relative energies of the ν(fp) orbitals is the driving force behind shell evolution. The first experimental study of states arising from the interaction between π(1s$_{1/2}$) and the orbitals ν(1p$_{3/2}$), ν(1p$_{1/2}$) and ν(0f$_{5/2}$) has been conducted, by way of the ^{47}K(d,p) reaction in inverse kinematics. A beam of radioactive ^{47}K ions was delivered by the GANIL-SPIRAL1+ facility, with a beam energy of 7.7 MeV/nucleon. This beam was estimated to be > 99.99% pure, with a typical intensity of 5 × 10^5 pps, and was impinged upon a 0.13 mg/cm^2 CD$_2$ target. The MUGAST+AGATA+VAMOS detection setup [5] allowed for triple coincidence gating, providing a great amount of selectivity. An analysis based both on excitation and gamma-ray energy measurements has revealed a number of previously unobserved states, and preliminary differential cross sections for the most strongly populated of these states will be presented. [1] D. Steppenbeck et al., Nature 502, 207 (2013). [2] O. Sorlin and M.-G. Porquet, Prog. Part. Nucl. Phys. 61, 602 (2008). [3] J. Papuga et al., Phys. Rev. C, 90 034321 (2014). [4] L. Gaudefroy, Phys. Rev. C, 81, 064329 (2010). [5] M. Assié et al., Nucl. Instrum. Methods A 1014, 165743 (2021).

[251] Study of (p,2p) events at the CALIFA calorimeter in knockout induced fission of 238U (17:30)

Presenter: GARCÍA JIMÉNEZ, Gabriel

Nuclear fission has been used as a tool for the study of nuclear propierties since its discovery in 1939. A new approach was performed in the context of the R3B collaboration, at the FAIR facilities, in which knockout reactions were used to induce fission in ^{238}U, which will allow to characterise the excitation energy of the process. The CALIFA calorimeter, a key part of the set-up, will be used to reconstruct the momentum of the two protons coming out the $(p,2pf)$ reaction. Preliminary results show that kinematic variables are well reconstructed and in good agreement with theory.

[179] A new scattering chamber for precision experiments on the heavy-ion reaction cross sections at the accelerator DC-60 (Nur-Sultan, Kazakhstan) at low energies (17:35)

Presenter: КУТЕРБЕКОВ, Кайрат

Within the framework of the long-term program of cooperation between JINR, ENU and Institute of Nuclear Physics (INP), joint experiments connected with the peculiarities of the interaction of lithium nuclei (6-9,11Li) at energies near the Coulomb barrier will be conducted on the U-400M cyclotron of G.N. Flerov Nuclear Reaction Laboratory (FLNR JINR) and on the DC-60 accelerator (Nur-Sultan) of the INP. To obtain new experimental information on the properties of weakly bound (cluster and exotic) lithium nuclei (the entire chain of lithium isotopes) and their manifestation in interaction with other nuclei, the features of the angular distributions of elastic and inelastic scattering cross sections, the energy dependences of the total reaction cross sections σR(E) and cross sections of individual dominant reaction channels; the corresponding reaction mechanisms in the previously unexplored region of energy will be studied. Experiments in Nur-Sultan (Kazakhstan) are supposed to be carried out at the DC-60 using a new scattering chamber and corresponding detector systems and nuclear electronics, which was manufactured at the FLNR JINR. The new dispersion chamber for the DC-60 is a completely new modern installation, which includes a new electronic system for collecting and processing experimental information FASTER. Control experiments using the new camera will be conducted on beams 6,9,11Li at the FLNR JINR and on 7Li nuclei on the DC-60. These nuclei (6,7,9Li) have a weakly bound cluster structure, and the 11Li nucleus is an exotic nucleus with a very low binding energy (Ebind = 0.3 MeV). In such experiments, we are expected to detect the features of their manifestation in nuclear reactions near the Coulomb barrier: subbarrier fusion, an increase in the cross section for cluster transfer reactions, features in the angular distributions of elastic and inelastic scattering, and features in σR(E). The obtained information is of great importance for fundamental nuclear physics and in other fields of science, for example, for describing the scenario of nucleosynthesis in astrophysics.

[180] Neutron transfer reaction 181Ta(18O, 19O) (17:40)

Presenters: AZHIBEKOV, Aidos, КУТЕРБЕКОВ, Кайрат

The study of nucleon transfer reactions is an important area of heavy ion physics because these reactions provide the possibilities for the synthesis of new exotic nuclei. There are various methods of production of light exotic neutron-rich nuclei (light nuclei with an unusually high number of neutrons). Multi-nucleon transfer reactions are one of the tools to access neutron-rich oxygen isotopes. Its advantage is the low excitation energy of the formed reaction products leading to their higher survival probability (lower probability of their subsequent decay). This report presents of neutron transfer mechanism for the reaction 181Ta(18O, 19O). Numerical solution of the time-dependent Schrodinger equation (TDSE) is used for studying neutron transfer processes. TDSE allows us to visualize the dynamics of taking place processes [1-5]. The probabilities are calculated for neutrons transfer from outer shells of the target 181Ta. The results of calculations of transfer cross sections are in satisfactory agreement with experimental data [6] for reaction 181Ta(18O,19O). High probability of neutron transfer from the 181Ta nucleus to the 2s orbital of 18O nucleus at near-barrier energies has been yielded. In our previous work [6], differential cross sections for the formation of oxygen isotopes in the reaction 18O+181Ta have been measured at projectile nucleus energy 10A MeV on the high-resolution magnetic spectrometer MAVR. Theoretical analysis has been performed in the DWBA formalism using the FRESCO code under the assumption of sequential neutron transfer mechanism. 1 A.K.Azhibekov, V.V.Samarin, K.A.Kuterbekov, Time-dependent calculations for neutron transfer and nuclear breakup processes in 11Li+9Be and 11Li+12C reactions at low energy, Chinese Journal of Physics 65 (2020) 292. 2 Yu.E. Penionzhkevich, Yu.G. Sobolev, V.V. Samarin et al., Energy dependence of the total cross section for the 11Li+28Si reaction, Phys. Rev. C 99 (2019) 014609. 3 Yu.E. Penionzhkevich, Yu.G. Sobolev, V.V. Samarin, M.A. Naumenko, Peculiarities in total cross sections of reactions with weakly bound nuclei 6He, 9Li // Physics of Atomic Nuclei 80 (2017) 928. 4 A.K. Azhibekov, Yu.E. Penionzhkevich, M.A. Naumenko et al., Probabilities of neutron transfer to single-particle levels in the reaction 181Ta(18O, 19O) at near-barrier energies // AIP Conference Proceedings 2377 (2021) 070001. 5 A.K. Azhibekov, Yu.E. Penionzhkevich et al., Dynamics of the Neutron Transfer Process in the Reaction 181Ta(18O, 19O) at an Energy of 10 MeV per Nucleon // Physics of Atomic Nuclei 84 (2021) 635. 6 A.K. Azhibekov, V.A. Zernyshkin, V.A. Maslov, Yu.E. Penionzhkevich et al., Differential Production Cross Sections for Isotopes of Light Nuclei in the 18O+181Ta Reaction // Physics of

Atomic Nuclei 83 (2020) 94.

[283] Investigation of shape evolution in 110Sn through Coulomb excitation (17:45)

Presenter: PARK, Joochun

The systematics of E2 transition probabilities along the Sn isotopic chain has received much attention in both experiment and theory. One of the latest Monte Carlo shell models suggested dynamic shape changes in the Sn isotopes and their excited states, while addressing the enhancement of B(E2) values towards ^{100}Sn. A safe-energy Coulomb excitation of ^{110}Sn was performed with the Miniball spectrometer at CERN HIE-ISOLDE. The beam energy was 4.4 MeV per nucleon, and the target was ^{206}Pb with a thickness of 4 mg/cm^2. High gamma-ray statistics and excitations beyond the first 2$^+$ state were observed, and a lifetime analysis was carried out with high precision. In addition to the B(E2) value, the intrinsic quadrupole moment of the 2$^+$ state in ^{110}Sn will be discussed for the first time. [On behalf of the Miniball collaboration]

Botafumeiro in the Cathedral - Facultad de Ciencias de la Comunicación (19:00 - 21:00)

Wednesday, 29 June 2022

WED1 - Facultad de Ciencias de la Comunicación (09:00 - 10:40)

-Conveners: Takashi Nakamura

[271] ONOKORO project --knockout reaction studies of clusters in heavy nuclei -- (09:00)

Presenter: UESAKA, Tomohiro

We have started a new research project named the ONOKORO project where we comprehensively investigate clustering in medium-to-heavy mass nuclei using (p,pX) cluster knockout reactions under normal and inverse kinematics. The research is motivated by our previous study on α clustering in $^{112-124}\mathrm{Sn}$ conducted at Research Center for Nuclear Physics, Osaka University [J. Tanaka, Z.H. Yang et al., Science 371, 260 (2021)]. The ONOKORO project will extend the study to d, t, $\mathrm{^3He}$, α clustering both in stable and unstable nuclei in the mass region of A=36—220. In the conference, we will present a physics background, research plan at RIBF, RCNP, and HIMAC facilities, and status of detector development for the inverse kinematics knockout experiments.

[260] Study of the 10Be(t,p)12Be reaction with the SOLARIS spectrometer (09:20)

Presenter: MUÑOZ RAMOS, Alicia

We present preliminary results of a recent experiment performed to measure the ^{10}Be(t,p)^{12}Be reaction with the SOLARIS solenoidal spectrometer. This is among the first experiments using a long-lived radioisotopes in conjunction with the re-accelerated beam facility (ReA6) at the Facility for Rare Isotope Beams. SOLARIS provides excellent resolution (about 150~keV FWHM) and background rejection capabilities for direct-reaction measurements. Using a re-accelerated ^{10}Be beam at 9.6~MeV/u on a titanium tritide target we observed bound states of ^{12}Be and those above the one- and two-neutron separation energies.The data reaffirm assignments and observations of a previous study in normal kinematics, while also offering new insights that hint at a resolution of some outstanding questions with regards to the structure of ^{12}Be. In this talk, we will discuss the experiment, the analysis procedure and the preliminary results. This material is based upon work supported by NSF's National Superconducting Cyclotron Laboratory which is a major facility fully funded by the National Science Foundation under award PHY-1565546; the U.S.\textbackslash Department of Energy, Office of Science, Office of Nuclear Physics, under Contract Number DE-AC02-06CH11357 (Argonne) and under Award Number DE-SC0014552 (UConn); Spanish Ministerio de Economía y Competitividad through the Programmes "Ramón y Cajal" with the grant number RYC2019-028438-I; the UK Science and Technology Facilities Council (Grant No. ST/P004423/1) (Manchester); and the International Technology Center Pacific (ITC-PAC) under Contract No. FA520919PA138. SOLARIS is funded by DOE Office of Science under the FRIB Cooperative Agreement DE-SC0000661.

[199] Consistent description of sequential and simultaneous contributions to the 11Li(p,t)9Li transfer reaction within a full three-body model (09:40)

Presenter: BURRELLO, STEFANO

A considerable amount of current lively research is devoted to the study of neutron Borromean nuclei, very intriguing exotic systems characterized by a diffuse two-neutron density distribution extending far beyond a compact core. Among them, the nucleus ^{11}Li deserves special attention, owing to the intensive theoretical and experimental work dedicated to this system in the last decades. The marked three-body structure of ^{11}Li renders three-body models particularly suitable to study its ground state and continuum properties. These models have also been very useful for the interpretation of reactions involving ^{11}Li. One of these models has been recently proposed and successfully applied to the analysis of one-neutron transfer [J.~Casal {\it et al.}, PLB767 (2017) 307] and quasi-free (p,pn) reactions [M.~Gomez-Ramos {\it et al.}, PLB 772 (2017) 115]. A key issue of this model is the inclusion of the ^{9}Li spin, which leads to a splitting of the $J^\pi=1^+,2^+$ resonances and $J^\pi=1^-,2^-$ virtual states. In this contribution, we employ this model to reanalyze the two-neutron transfer data for ^{11}Li(p,t)^{9}Li at 3 MeV/u [I. Tanihata {\it et al.}, PRL 100, 192502 (2008)]. We use the second order DWBA method, and include both sequential and simultaneous contributions. For the former, the required $\langle ^{11}\rm{Li} | ^{10}\rm{Li} \rangle$ overlaps are consistently evaluated from the three-body wave function of ^{11}Li. Our results will be compared with those obtained with previous analyses ignoring the spin of ^{9}Li.

[204] Application of the Nilsson Model to the structure and reactions of exotic weakly bound nuclei (10:00)

Presenter: PUNTA DE LA HERRÁN, Pedro

The structure of the deformed weakly-bound nuclei ^{17}C, ^{19}C and ^{11}Be has been studied within the strong-coupling limit, using the Nilsson model. A novel approach is used to obtain the energies and associated wave functions for bound states and some low-lying resonances of the system, consisting in diagonalizing the Nilsson Hamiltonian in a basis of transformed harmonic oscillator (THO) functions. This basis has been successfully applied to the discretization of the continuum of weakly bound nuclei applied to break up and transfer direct reactions both for two-body and three-body systems [Phys. Rev. Lett. 109 (2012) 232502, Phys. Revi. C 94 (2016) 054622]. To assess the quality and accuracy of the calculated wavefunctions, the latter have been used as ingredients to calculate differential cross sections of neutron transfer reactions in which one of these nuclei is involved. Considering the Adiabatic Distorted Wave Approximation(ADWA),the calculations are made for the reactions $^{11}\text{Be(p,d)}^{10}\text{Be}$ and $^{16}\text{C(d,p)}^{17}\text{C}$, being compared respectively with the experimental data from [Chin. Phys. Lett. 35 (2018) 082501] and [Phys. Lett. B 811 (2020) 135939].

[183] Determination of the neutron 0d3/2 strength in 17C. (10:20)

Presenter: LOIS, Juan

The evolution of the N=16 shell gap in neutron-rich oxygen isotopes has been studied extensively over the past years [1, 2, 3, 4]. In neutron-rich carbon isotopes, the N=14 shell gap is shown to collapse [5, 6]however no experimental information on the N=16 shell gap is known. Unbound states in 17C have been populated using one-neutron transfer reaction d(16C,p)17C at a beam energy of 17.2 AMeV [6] with the TIARA Silicon array at GANIL. The excitation energy of the neutron unbound states in 17C was reconstructed using the information from the energy and angle of the proton ejectile. Some resonances have been found and their neutron-decay widths were deduced. The results are compatible with a large strength of the 0d3/2 orbital involved in the development of the N=16 shell gap. In this talk, I will present the preliminary results and discuss them in the light of recent shell model calculations. References: [1] O. Sorlin and M.G. Porquet, Prog. Part. Nucl. Phys. 61 (2008) 602. [2] T. Otsuka et al., Rev. Mod. Phys. 92 (2020) 015002. [3] Z. Elekes et al., Phys. Rev. Lett. 98 (2007) 102502. [4] C. R. Hoffman et al., Phys. Rev. Lett. 100 (2008) 152502. [5] M. Stanoiu et al., Phys. Rev. C 78 (2008) 034315. [6] X. Pereira-López et al. Physics Letters B, 811, (2020), 135939

Coffee Break - Facultad de Ciencias de la Comunicación (10:40 - 11:20)

WED2 - Facultad de Ciencias de la Comunicación (11:20 - 13:00)

-Conveners: Alexandre Obertelli

[215] Cluster models of the 6Li + p --> 3He + alpha reaction at sub-Coulomb energies (11:20)

Presenter: PERROTTA, Salvatore Simone

The accuracy of several astrophysical models, as those describing elemental abundances in the Universe, is limited by the knowledge of cross-section for a wide number of nuclear reactions, often involving light charged reactants at low collision energies (< 100 keV). The reaction dynamics in such regime is dominated by the penetration of the Coulomb barrier. The process is also influenced by the presence of other electric charges in the surrounding environment, both in the astrophysical sites and in laboratory. For several reactions, combined information from available data on fixed-target direct measurements is in contrast with predictions given by atomic theory on the cross-section enhancement generated by atomic electrons [[1](https://doi.org/10.1016/j.physletb.2016.02.019 "C. Spitaleri et al., Physics Letters B 755 (2016), p. 275")]. A semi-classical model, which addresses the issue assuming a cluster structure for the nuclei involved in the reaction, was proposed in [[1](https://doi.org/10.1016/j.physletb.2016.02.019 "C. Spitaleri et al., Physics Letters B 755 (2016), p. 275")]. The goal of the present work is instead to perform a theoretical study from a purely quantum perspective, by explicitly evaluating the nuclear reaction cross-section for a given process by employing a more sophisticated model for the reactants structure and interactions. In this talk, we examine the ^{6}Li + p $\to$ ^{3}He + α reaction, one of those for which an anomalous enhancement has been found [[1](https://doi.org/10.1016/j.physletb.2016.02.019 "C. Spitaleri et al., Physics Letters B 755 (2016), p. 275"),[2](https://doi.org/10.1088/0004-637X/768/1/65 "L. Lamia et al., The Astrophysical Journal 768 (2013), p. 65")]. Reactions destroying ^{6}Li are also interesting for studying pre-main-sequence stars, with respect to the lithium-depletion problem (see [[2](https://doi.org/10.1088/0004-637X/768/1/65 "L. Lamia et al., The Astrophysical Journal 768 (2013), p. 65")] and references therein), and in the context of controlled nuclear fusion energy production [[3](https://doi.org/10.1088/0029-5515/11/2/013 "J. R. McNally, Nuclear Fusion 11 (1971), p. 187")]. The process was described as a direct transfer of a deuteron or of two nucleons. We performed first- and second-order distorted-wave Born approximation calculations using the Fresco code [[4](https://doi.org/10.1016/0167-7977(88)90005-6 "I. J. Thompson, Computer Physics Reports 7 (1988), p. 167")], from energies around the Coulomb barrier ($\sim$1.5 MeV) down to those relevant for the electron screening problem and astrophysical applications ($\sim$10 keV). The impact on the transfer cross-section of quadrupole deformations and of the strenght of clustered configurations in ^{6}Li ground-state will be discussed. [1] [C. Spitaleri et al., Physics Letters B 755 (2016), p. 275](https://doi.org/10.1016/j.physletb.2016.02.019) [2] [L. Lamia et al., The Astrophysical Journal 768 (2013), p. 65](https://doi.org/10.1088/0004-637X/768/1/65) [3] [J. R. McNally, Nuclear Fusion 11 (1971), p. 187](https://doi.org/10.1088/0029-5515/11/2/013) [4] [I. J. Thompson, Computer Physics Reports 7 (1988), p. 167](https://doi.org/10.1016/0167-7977(88)90005-6)

[232] Core-valence absorption in breakup reactions: a source of binding-energy asymmetry in nucleon removal observables? (11:40)

Presenter: GOMEZ RAMOS, Mario

Nucleon removal reactions at intermediate energies have proven to be a powerful tool to extract spectroscopic information from atomic nuclei. Despite their extensive use, there remain some open questions in their description. In particular since the early 2000s, a trend was noticed in which cross sections for nucleon knockout with heavy targets was found to be significantly overestimated for the removal of deeply-bound nucleons in asymmetric nuclei, while the removal of the weakly-bound species in these same nuclei did not present such an overestimation [1]. The fact that this trend has not been observed in transfer or knockout reactions with proton targets (p, pN) urges for the reevaluation of the description for these reactions [2]. An effect that is usually left out of the description of nucleon knockout reactions that could, at least partially, explain this trend is the absorption due to the interaction between the removed nucleon and the residual nucleus (core) after the breakup of the projectile. Since nucleon and core are left in a state of medium or high relative energy, their interaction can lead to the destruction of the core and a subsequent reduction of the cross section. This effect would naturally be more intense in the removal of more deeply-bound nucleons, which interact more strongly with the core. As a first step to assess the importance of this effect, in this contribution we study it in nucleon elastic breakup reactions, in which both nucleon and residual core are detected after the collision. We extend the usual description via Continuum-Discretized Coupled-Channels (CDCC) [3] to include the absorption between nucleon and core through an expansion in the eigenstates of a complex potential which describes this absorption, correcting for their non-orthogonality through the use of a biorhogonal basis [4]. This extended CDCC formalism is then applied to neutron breakup of 11 Be and 41 Ca on 12 C targets at energies of 70 MeV/A. We find a significant reduction for the more deeply-bound neutron in 41 Ca and only a moderate one for 11 Be, which is similar to the reduction factors found in nucleon knockout reactions. [1]A. Gade et al, Phys. Rev. C 77, 044306 (2008) [2]T. Aumann et al, Prog. Part. Nucl. Phys. 118, 103847 (2021) [3]N. Austern et al, Phys. Rep. 154, 125 (1987) [4]B. H. McKellar and C. M. McKay, Aust. Jour. Phys. 36, 607 (1983)

[255] LATEST NEWS ON FRAISE, THE NEW FRAGMENT IN-FLIGHT SEPARATOR AT INFN- LNS (12:00)

Presenter: PAGANO, Emanuele Vincenzo

Radioactive Ions Beams (RIBs) have been produced at Laboratori Nazionali del Sud (LNS-INFN) since 2001 by means of the In-Flight fragmentation method [1-3]. With the upgrade of the laboratory thanks to the ambitious and massive upgrade project (POTLNS) the extraction technique of the K800 Superconducting Cyclotron will be improved and one of the goals is to deliver light and medium masses nuclei with a power up to ≈ 10 kW. This project opens further perspectives to produce RIBs. A dedicated facility of a new fragment separator FRAISE (FRAgment In-Fight SEparator) is on the way, to exploit the primary beams, with a power of ≈ 3-4 kW, for the production of high-intensity and high-quality RIBs [1-3]. The high beam intensity achieved with FRAISE requires the use of diagnostics and tagging systems able to operate in a strong radioactive environment and in a wide intensity range. In the contributions will be present the status of the upgrade and some RIBs possibilities. References [1] Russotto P. et al., Jour. of Phys. Conf. Ser., 1014 (2018) 012016 and references therein. [2] Russo A.D. et al., NIM B, 463 (2020) 418. [3] Martorana N.S., Il Nuovo Cimento 44 C (2021) 1.

[195] Study of the Coulomb dissociation of the exotic nuclei using Coulomb dynamical polarization potential (12:20)

Presenter: MARIDI, Hasan

In our recent work [1], we presented a new expression for the coulomb dynamical polarization potential (CDPP) and the electric dipole polarizability of light exotic nuclei with a two-body deuteronlike cluster structure. The Schrödinger equation for the internal motion of the exotic projectile incident on a heavy target nucleus is solved using the adiabatic approximation. Then, this CDPP was applied to different cluster structures of ^{6}He and ^{8}He *emphasized text*and comparisons of the effect of breakup coupling and $1n$ stripping reaction on the elastic scattering of these projectiles from a ^{208}Pb target, at incident energies below the Coulomb barrier, has been performed [2]. In this work, this CDPP is extended to include the excitations of the projectile clusters and then, a novel method is presented to study the Coulomb dissociation of exotic nuclei at high energies. The results of the calculations are in good agreement with the Coulomb dissociation data. We acknowledge support from the Polish National Agency for Academic Exchange (NAWA) within the Ulam Programme under Grant Agreement No. PPN/ULM/2019/1/00189/U/00001. 1. H. Maridi, K. Rusek, and N. Keeley, Phys. Rev. C 104, 024614 (2021). 2. H. Maridi, K. Rusek, and N. Keeley, accepted at Eur. Phys. J. A (2022).

[229] Study of the elastic scattering and one-neutron stripping channel in the ^{8}Li+^{58}Ni collision (12:40)

Presenter: SANTOS, O. C. B. dos

Recent experimental measurements for the ^{8}Li+^{58}Ni system at 23.9, 26.1, 28.7 and 30 MeV bombarding energies have been obtained using the RIBRAS facility [1-4]. A strong production of ^{7}Li particles has been observed from the breakup of the ^{8}Li into ^{7}Li+n and the one neutron transfer reaction of the ^{8}Li projectile to the ^{58}Ni target. The ^{7}Li angular distributions have been analyzed considering the Coupled-Reaction Channels (CRC) formalism, which includes the coupling of the elastic channel to the ^{59}Ni=^{58}Ni+n states below and above the neutron threshold. The CRC calculations provided a simultaneous description of both, the ^{7}Li and the elastic scattering angular distributions. Furthermore, the angular and energy distributions of ^{7}Li particles have been simultaneously well described considering the combination of the

Ichimura-Austern-Vincent (IAV) model [5,6] and Continuum Discretized Coupled Channels (CDCC) methods, for the inelastic and elastic breakup respectively. References [1] O. C. B. Santos and et al. Phys. Rev. C 103, 064601 (2021). [2] A. Lépine-Szily, R. Lichtenthäler, and V. Guimarães, Eur. Phys. J. A 50, 128 (2014). [3] R. Lichtenthäler and et al, Eur. Phys. J. A 57, 92 (2021). [4] R. Lichtenthäler and et al, Eur. Phys. J. A 25, 733 (2005). [5] M. Ichimura, N. Austern, and C. M. Vincent, Phys. Rev. C 32, 431 (1985). [6] J. Lei and A. M. Moro. Phys. Rev.C 92, 044616 (2015).

Lunch + Excursion - Facultad de Ciencias de la Comunicación (13:00 - 20:00)

Thursday, 30 June 2022

THU1 - Facultad de Ciencias de la Comunicación (09:00 - 10:40)

-Conveners: Wilton Catford

[201] Invariant-mass Spectroscopy of 10He from 11Li(p,2p} reaction at ~250 MeV/nucleon (09:00)

Presenter: SUN, Yelei

Starting from the pioneering work of Korsheninnikov ${et}$ ${al}$. [1], several experiments have been carried out to study the resonance states in ^{10}He [1-5]. However, up to now, the energy of ^{10}He ground state resonance is still under debate. In this talk, I will report on the three-body invariant-mass spectroscopy of ^{10}He populated via the (${p}$,2${p}$) reaction from 2${n}$-halo nucleus ^{11}Li at ~250 MeV/nucleon. The obtained ^{10}He spectrum, with much higher statistics than previous two measurements [1,2], was compared to the theoretical calculation that combines the coupled-channel three-body model of ^{11}Li [6] and the quasi-free knockout (${p}$, ${pN}$) reaction model [7,8]. Two low-lying 0^{+} states of ^{10}He were identified at ~ 1 MeV and at ~2 MeV, which have a $[s_{1/2}s_{1/2}]_{0^{+}}$ configuration and a $[p_{1/2}p_{1/2}]_{0^{+}}$ configuration, respectively. The three body corrections in Jacobi T and Jacobi Y coordinates were also extracted and compared to the model predictions. Our study shed light into the long standing puzzle about the different ^{10}He ground state energy obtained from knockout and transfer reactions. [1] A. A. Korsheninnikov ${et}$ ${al}$., Phys. Lett. B 326, 31 (1994). [2] H. T. Johansson ${et}$ ${al}$., Nucl. Phys. A842, 15 (2010). [3] Z. Kohley ${et}$ ${al}$., Phys. Rev. Lett. 109, 232501 (2012). [4] S. I. Sidorchuk ${et}$ ${al}$., Phys. Rev. Lett. 108, 202502 (2012). [5] P. G. Sharov ${et}$ ${al}$., Phys. Rev. C 90, 024610 (2014). [6] Y. Kikuchi ${et}$ ${al}$., Phys. Rev. C 87, 034606 (2013). [7] Y. Kikuchi ${et}$ ${al}$., Prog. Theo. and Expt. Phys, 2016 (2016). [8] Y. Kubota ${et}$ ${al}$., Phys. Rev. Lett. 125, 252501 (2020).

[221] From chiral EFT NN interaction to nucleus-nucleus optical potentials (09:20)

Presenter: DURANT, Victoria

The determination of the interaction between projectile and target is one of the long-standing challenges in the study and description of nuclear reactions. These interactions are important inputs to compute reaction observables, which have applications in various fields of nuclear physics, like nuclear structure far from stability or reactions of astrophysical interest. Applying the double-folding technique, we determine potentials relevant for nuclear reactions based on the interaction between nucleons and the densities of the reacting nuclei. To this end, we use chiral EFT nucleon-nucleon interactions at N^{2}LO in their local form [1]. Since this technique naturally leads to an energy dependence, we consider dispersion relations to constrain the imaginary part of the optical potential. With this approach we study reactions involving light nuclei such as α, ^{12}C, ^{16}O, and ^{20}O [2, 3]. We present results for elastic scattering off various targets, as well as for low-energy fusion. We obtain good agreement with data without any parameter fitting. Our analysis has enabled us to study the impact of the nuclear density and the nucleon-nucleon interaction on the corresponding cross sections. Thanks to the predictive power of this technique, we can calculate various reaction observables reliably without adjusting any parameter. [1] A. Gezerlis, I. Tews, E. Epelbaum, M. Freunek, S. Gandolfi, K. Hebeler, A. Nogga, and A. Schwenk, Phys. Rev. C 90, 054323 (2014). [2] V. Durant, P. Capel, L. Huth, A. B. Balantekin, and A. Schwenk, Phys. Lett. B 782, 668 (2018). [3] V. Durant and P. Capel, Phys. Rev. C 105, 014606 (2022).

[189] Nuclear structure near decay thresholds (09:40)

Presenter: VOLYA, Alexander

The quantum many-body dynamics is influenced by the coupling to the continuum of reaction states. This influence is particularly strong near the decay threshold causing structural changes in the wave functions relative to the decay channels. Threshold discontinuities, collectivization of states relative to decay channels, clusterization, symmetry breaking, and interplay of decay and internal dynamics are all remarkable manifestations of quantum many-body physics at the verge of stability. In this presentation we discuss recent experiments on alpha clustering that show strong correlations between alpha clustering structure and the corresponding decay thresholds; isobaric mirror resonant reactions provide further insight into competition between clustering and other features of the many-body dynamics. We also discuss recent studies of few-body decays, both direct and sequential, as well as the dynamics involving virtual excitations.

[178] Microscopic optical potentials: recent achievements and applications. (10:00)

Presenter: FINELLI, Paolo

Nucleon elastic scattering is a very important process to understand nuclear interactions in finite nuclei. Even if this process has been extensively studied in the last years, a consistent microscopic description is still under development. In this perspective, our long term project was to study the domain of applicability of microscopic two- and three-body chiral forces in the construction of an optical potential (OP) with the ultimate goal to obtain a consistent description of both the target and the projectile-nucleus dynamics. In general, the OP is obtained as the first-order term within the spectator expansion of the multiple scattering theory and adopting the impulse approximation. As a first step, we derived a nonrelativistic theoretical optical potential from nucleon-nucleon chiral potentials at fourth (N3LO) and fifth order (N4LO). We checked convergence patterns and establish theoretical error bands for Wolfenstein amplitudes and the cross sections, analyzing powers, and spin rotations of elastic proton scattering off some light nuclei at an incident proton energy of 200 MeV [1,2]. Then, we extended our analysis to the cross sections and analyzing powers of calcium, nickel, tin, and lead isotopes exploring the range $156 \le E \le 333$ MeV, where experimental data are available. In addition, we provided theoretical predictions for Ni56 at 400 MeV, which is of interest for the experiments at EXL [3]. In the last years we explored the impact of three-body forces [4] and how the developed formalism could be applied to non-zero spin targets [5]. In conclusion, we also performed some predictions for antiproton elastic scattering off nuclei at energies close to 200 MeV [6], in remarkable agreement with experimental data. Recent works in connection with the Ab-Initio Self-Consistent Green Functions method will also be presented [7]. Our results clearly indicate that microscopic optical potentials derived from nucleon-nucleon chiral potentials can provide reliable predictions for the cross section and the analyzing power of stable and exotic nuclei. Bibliography [1] M. Vorabbi, P. Finelli, C. Giusti, Phys. Rev. C93, 034619 (2016) [2] M. Vorabbi, P. Finelli, C. Giusti, Phys. Rev. C96, 044001 (2017) [3] M. Vorabbi, P. Finelli, C. Giusti, Phys. Rev. C98, 064602 (2018) [4] M. Vorabbi, M. Gennari, P. Finelli, C. Giusti, P. Navratil et al., Phys. Rev. C103 024604 (2021) [5] M. Vorabbi, M. Gennari, P. Finelli, C. Giusti, P. Navratil et al., Phys. Rev. C105 014621 (2022) [6] M. Vorabbi, M. Gennari, P. Finelli, C. Giusti, P. Navratil et al., Phys. Rev. Lett. 124, 162501 (2020) [7] M. Vorabbi ,C. Barbieri ,V. Somà ,P. Finelli , and C. Giusti, in preparation (2022)

[193] Halo-EFT description of halo nuclei within one-neutron removal reactions (10:20)

Presenter: HEBBORN, Chloë

Since their discovery, halo nuclei have challenged usual nuclear-structure models. These exotic nuclei exhibit a strongly clusterized structure, in which one or two loosely-bound nucleons have a high probability of presence far from the others, forming a diffuse halo around them. One-neutron removal reactions are often used to probe the single-particle structure of halo nuclei since they exhibit high counting statistics thanks to the loose binding of the halo to the rest of the nucleons. In this work, we reanalyze the one-neutron knockout measurements of $^{11}\rm Be$ and $^{15}\rm C$ on beryllium at about 60 MeV/nucleon, considering effective field theory (Halo-EFT) descriptions of $^{11}\rm Be$ and $^{15}\rm C$. We show that constraining the parameters of the Halo-EFT with *ab initio* predictions leads to an excellent agreement with the experimental data. This shows that Halo-EFT can be reliably used to analyze one-neutron knockout reactions measured for halo nuclei and test predictions from state-of-the-art nuclear structure models on these experimental data. This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under the FRIB Theory Alliance Award No. DE-SC0013617 and by LLNL under Contract No. DE-AC52-07NA27344.

<u>Coffee Break</u> - Facultad de Ciencias de la Comunicación (10:40 - 11:20)

<u>THU2</u> - Facultad de Ciencias de la Comunicación (11:20 - 13:00)

-Conveners: Marina Petri

[244] Neutron-proton pairing in the self-conjugate unstable nuclei 56Ni and 52Fe through transfer reactions (11:20)

Presenter: ASSIE, Marlène

Neutron-proton pairing is the only pairing that can occur in the T=0 and the T=1 isospin channels. T=1 particle-like pairing (n-n or p-p) has been extensively studied unlike T=0 neutron-proton pairing. The over-binding of N=Z nuclei could be one of its manifestation. Neutron-proton pairing can be studied by spectroscopy as in ref.[1].We have studied it through transfer reactions in order to get more insight into the relative intensities of the two aforementioned channels. Indeed, the cross-section of np pair transfer is expected to be enhanced if the number of pairs contributing to the populated channel is important. The observable of interest is the ratio of the two-nucleon transfer cross-sections to the lowest 0+ and 1+ states. Neutron-proton pairing is predicted to be more important in N=Z nuclei with high J orbitals so that the best nuclei would belong to the g9/2 shell [2]. However, considering the beam intensities in this region, we have focussed on fp shell nuclei. The measurement was performed at GANIL with radioactive beams produced by fragmentation of a 75A MeV 58Ni beam on a 185 mg.cm-2 Be target purified by the LISE spectrometer. An efficient set-up based on the coupling of the MUST2 and TIARA Silicon arrays for charged particle detection with the EXOGAM gamma-ray detector was used. Measuring the two-nucleon transfer reaction (p,3He) for both 52Fe (N=Z=26) which is a partially occupied 0f7/2 shell nucleus and 56Ni (N=Z=28) which has a fully occupied 0f7/2 shell allows us to study np pairing according to shell occupancy. I will present the cross-sections measured in both channels (T=0 and T=1) and discuss the consequence for each pairing channel. The aforementioned ratio of cross-section and the angular distribution for the ground state of 54Co will be compared with DWBA calculations [3]. [1] B. Cederwall et al, Nature 469 (2011) 469. [2] P. van Isäcker et al, Phys. Rev. Lett. 94 (2005) 162502. [3] B. Le Crom et al, Phys. Lett. B (2022) to appear.

[200] Unbound states in ^{16,18,20}C with the R^{3}B/LAND setup: the search for the mixed-symmetry 2^{+} state (11:40)

Presenter: MURILLO MORALES, Silvia

The evolution of the traditional nuclear magic numbers away from the valley of stability has gathered attention in recent years. Experimental efforts focus on obtaining key spectroscopic information that will provide great insight into the structure of exotic nuclei in order to understand the driving mechanism behind the shell evolution. Recently, $\rm ^AN$(p,2p)$\rm ^{A-1}C$ quasi-free scattering reactions, employed at the R3B/LAND setup at GSI, extracted the proton component of the 2^+_1 state of ^{16,18,20}C in order to probe the proton $1p_{1/2} − 1p_{3/2}$ spin-orbit splitting towards the neutron dripline. These results reported a moderate quenching of the Z=6 sub shell closure [1]. We work upon the model of a two-state mixing of pure proton and pure neutron excitations to describe excited 2$^+$ states in neutron-rich carbon isotopes [2,3]. The coupling of the unperturbed proton and neutron 2$^+$ states should give rise to a second 2$^+$ state of mixed symmetry character, expected to be unbound and strongly populated via (p,2p) reactions. This work focuses on identifying these strongly populated unbound mixed-symmetry 2^+ states in ^{16}C, ^{18}C and ^{20}C. The preliminary results of this work will be presented, and its implications for the Z=6 shell gap will be discussed. [1] I. Syndikus et al., Probing the $\mathrm{Z}=6$ spin-orbit shell gap with (p,2p) quasi-free scattering reactions, Physics Letters B (2020). [2] M. Petri et al., Phys. Rev. C. 86, 044329 (2012). [3] A. O. Macchiavelli et al. Phys. Rev. C 90 067305 (2014).

[234] Direct reactions studies with ACTAR TPC: highlights from the first transfer experiment at GANIL (12:00)

Presenter: FERNANDEZ DOMINGUEZ, Beatriz

Direct reactions are fundamental tools to investigate the structure of exotic nuclei. Studies of nuclei far away from stability are usually performed with secondary radioactive beams, that suffer from low intensities and need to be compensated with thick targets and high efficient detection systems to increase luminosity. Active targets are invaluable devices that, among other important features, allow to reconstruct the reaction in three dimensions without loss of resolution. The ACtive TArget and Time Projection Chamber (ACTAR TPC) detector has been developed at GANIL to cover a broad physics programme. The device was commissioned in 2018 showing an excellent performance of the detector. Since then, several experiments have been performed at GANIL. In this talk, I will present the physics motivation and some preliminary results with special focus on the foreseen achievements for transfer reactions with active targets.

[235] Observation of a Near-Threshold Proton Resonance in 11B (12:20)

Presenter: ALMARAZ-CALDERON, Sergio

Experiments looking for near-threshold resonances in weakly bound nuclei provide a direct link between nuclear reactions and nuclear structure, via the interaction of discrete states with the continuum. These states, located near the particle-decay threshold, accumulate most of the continuum strength in a single state and couple strongly to the decay-channel, exhausting most of the decay-width and carrying many of its characteristics. In particular, a near-threshold proton resonance in 11B has long been sought since it would be the intermediate state that may help explain the controversially large β−p+ branching ratio from the 11Be nucleus that has been observed in experimental measurements but is not in full agreement with theoretical calculations. In this works I will discuss a recent experiment carried out at the John D. Fox Superconducting Linear Accelerator Laboratory at Florida State University where the near threshold proton resonance at 11.4 MeV in 11B was observed for the first time, via the 10Be(d,n)11B reaction. The results and implications of our measurement will also be presented.

[237] Total Reaction Cross-Section Measurements in the Commissioning Experiment for R3B (12:40)

Presenter: PONNATH, Lukas

The $R^{3}B$ (Reactions with Relativistic Radioactive ion Beams) experiment at the research facility FAIR, currently under construction in Darmstadt, enables kinematically complete reaction studies for the most exotic nuclei. The S444 commissioning experiment for $R^{3}B$, performed in the FAIR Phase-0 campaign in 2019, was the first operation of many new $R^{3}B$ detectors in a common setup. With a stable ^{12}C beam and a set of different beam energies ranging from 400AMeV to 1AGeV we challenged this large acceptance installation around the GLAD magnet using the $^{12}C(p,2p)^{11}B$ benchmark reaction. During this successful commissioning we could measure the energy dependence of total reaction cross-sections of a ^{12}C beam on a ^{12}C target, which is poorly known for energies above 400AMeV. This is an important input for current calculations based on the eikonal reaction theory. In my Talk I will present the current status and preliminary results of the analysis and discuss the technique and evaluated error budget for the different steps, also applicable for exotic nuclei in the future. (supported by BMBF 05P19WOFN1, 05P21WOFN1 and the FAIR Phase-0 program)

Lunch Break - Facultad de Ciencias de la Comunicación (13:00 - 14:40)

THU3 - Facultad de Ciencias de la Comunicación (14:40 - 16:20)

-Conveners: Hector Alvarez Pol

[197] Study of the two-neutron decay of 13Li via the invariant mass method with SAMURAI@RIBF (14:40)

Presenter: ANDRÉ, Paul

^{13}Li is a neutron-rich unbound nucleus that decays into the halo nucleus ^{11}Li via the emission of two neutrons. Studying such a system can lead to a better understanding of neutron-neutron correlations in the atomic nucleus. This study has been performed using the SAMURAI facility [1] at RIBF, RIKEN, Japan, with a high-intensity beam and a setup with large acceptance, allowing a better resolution and efficiency than achieved in past measurements at GSI [2] and NSCL [3]. A beam of 14Be impinges on the liquid hydrogen MINOS target [4], producing the ^{13}Li isotopes via a (p,2p) reaction. The vertex of interaction is then reconstructed thanks to the tracking system around the target. The two decay neutrons are detected in the NEBULA array, and the remaining ^{11}Li is detected in a hodoscope [5]. Thanks to the reconstruction of the momenta of all the decay products with the aforementioned detectors, the invariant masses of the ^{11}Li-n-n system, the ^{11}Li-n system and the n-n system are computed. With this quantity, more information on the spectroscopy of ^{13}Li, such as the energy of the neutron resonances, can be provided. Using correlation plots of the Jacobi coordinates of the system [6], information on the nature of the decay (e.g. sequential or direct) can also be deduced. [1] T. Nakamura, Y. Kondo, Nucl. Instrum. Methods Phys. Res. B 376 (2016) 156-161 [2] Yu. Aksyutina et al., Phys. Lett. B 666 (2008) 430-434 [3] Z. Kohley et al., Phys. Rev. C 87 (2013) 011304(R) [4] A. Obertelli et al., Eur. Phys. J A 50 (2014) [5] T. Kobayashi et al., Nucl. Instrum. Methods Phys. Res. B 317 (2013) 294-304 [6] R.J. Charity et al., Phys. Rev. C 84 (2011) 014320

[188] Exclusiv one-nucleon removal from 14O at ~100 MeV/nucleon (15:00)

Presenter: POHL, Thomas

One-nucleon removal reaction at intermediate energies has been a powerful tool for single-particle structure studies of exotic nuclei [1], but the reaction mechanism is not fully understood [2-5]. One debated phenomenon is the asymmetric parallel momentum distribution (PMD) of the residual nucleus occuring occasional in one nucleon removal induced from light ion-targets [4,6,7]. Recent theoretical calculation of (p,pN) reactions with ^{14}O at 100 MeV/nucleon with the distorted-wave impulse approximation (DWIA) predicted also large asymmetric PMD for deeply-bound nucleon removal [5]. The low momentum tail is found to be due to the attractive potential between the residues and the outgoing nucleons and the steep falloff on the high momentum side is due to the energy and momentum conservation. Still, comparison with experimental data is necessary for validation and will be a basis for further spectroscopic factor studies. We have performed ^{14}O(p,pN)^{13}O and ^{14}O(p,$2p$)^{13}N reactions at $\sim$100 MeV/nucleon with a thin solid hydrogen target at SAMURAI at RIKEN. Momentum of the residues were extracted from the SAMURAI spectrometer. Details of the data analysis and results of the cross section and PMD will be presented. [1] T. Aumann $et\: al.$, Prog. Part. Nucl. Phys. 118, 103847 (2021). [2] C. Louchart, A. Obertelli $et\: al.$, Phys. Rev. C 83, 011601(R) (2011). [3] Y.L. Sun, A. Obertelli $et\: al.$, Phys. Rev. C 93, 044607 (2016). [4] F. Flavigny $et\: al.$, Phys. Rev. Lett. 108, 252501 (2012). [5] K. Ogata $et\: al.$, J. Phys. Rev. C 92, 034616 (2015). [6] A. Gade $et\: al.$, Phys. Rev. C 71, 051301(R)(2005). [7] K.L. Yurkewicz $et\: al.$, Phys. Rev. C 74, 024304 (2006).

[209] Study of the magicity of the 13B nucleus and mixed configurations in 12Be via QFS knockout reactions. (15:20)

Presenter: BARRIERE, Antoine

The ^{13}B(p, pn)^{12}B and ^{13}B($p, 2p$)^{12}Be reactions have been used at about 470 MeV/A with CH2 and C targets to study the shell structure of two N = 8 isotones. The ^{13}B nuclei were produced by the FRS-GSI facility and transmitted to the R3B-LAND beam line where the γ-sphere Crystal Ball and the neutron detector Land were used to determined the cross section of the bound and unbound states in ^{12}B and ^{12}Be nuclei, in which the energy and J^π values of almost all populated states were previously assigned. In case of a strong N = 8 shell closure in the ^{13}B nucleus, the $0p_{1/2}$ neutron orbital (the normal configuration) is expected to be fully occupied, with a negligible fraction of occupancy for the valence $1s_{1/2}$ and $0d_{5/2}$ orbitals (the intruder one). In such a case, the neutron removal reaction will not populate states of negative parity constructed with these intruder configurations. From the small content of intruder $1s0d$ states that we found, it is deduced that the magicity at N = 8 is strongly preserved in ^{13}B, similarly to the doubly magic nucleus ^{14}C, before suddenly collapsing in ^{12}Be where the intruder content is by far dominating. Our results are globally in agreement with those extracted from the ^{13}B(p,d)^{12}B transfer reaction [1]. From the ^{13}B($p,2p$)^{12}Be reaction, we obtained the sum of the 0^{+}_{1} and 0^{+}_{2} isomeric state, the feeding of the 2^{+}_{1} bound state as well as the one of the 2^{+}_{2} resonance state [2]. By using the wave functions of the 0^{+}_{1} and 0^{+}_{2} states proposed by Chen et al. [3], and that of ^{13}B deduced from our study of ^{13}B(p,pn)^{12}B reaction, we find that the one-proton removals reactions to the 0^{+}_{1} and 0^{+}_{2} states in ^{12}Be have similar cross sections. As for the 2^{+}_{2} state, we have observed its decays to the ground and first excited states of ^{11}Be, as well as to the ground state of ^{10}Be by $2n$ emissions. This clarifies the controversy on its decay and nature from the works of Fortune [4] and Smith et $al.$[5]. The cross section to the 2^{+}_{2} state is about 8 times larger than that of the 2^{+}_{1} state. We therefore conclude that the two 0^+ states exhibit more mixing than the 2^+ does, and that the 2^{+}_{2} state is a candidate for the spherical band in ^{12}Be. [1] W. Liu et $al.$, Phys. Rev. C 104, 064605 (2021) [2] A. Kamenyero, "Structure of ^{12}Be via the study of multi-neutron decays and two-neutron correlations", PhD thesis, University of Caen (2022) [3] J. Chen et $al.$, Phys. Lett. B 781, 412 (2018) [4] H. T. Fortune, Eur. Phys. J A 52, 11 (2016) [5] J. K. Smith et $al.$, Phys. Rev. C 90, 024309 (2014)

[268] Systematic measurement of nucleon removal cross sections in the vicinity of doubly magic 78Ni (15:40)

Presenter: TANIUCHI, Ryo

Nucleon removal reactions from atomic nuclei are connected both with the nuclear structures and the reaction mechanisms. Systematic studies in the vicinity of magic numbers are of importance to test our understandings of the nuclear structure as such reactions involve not only the valence nucleons but also the nucleons across the shell gap. In a recent study, an anomalously small inclusive cross section of 79Cu for a one-proton knockout reaction at intermediate energy compared with the other isotones, 80Zn and 81Ga. It has been interpreted as most of the contribution of the cross sections feeds to the unbound states due to the large shell gap across the Z=28 proton shell. To assess the lack of the cross sections systematically and with reduced uncertainties, an experiment aiming to measure nucleon removal cross sections in the vicinity of the doubly magic isotope 78Ni at the RIKEN RI Beam Factory has been conducted. Secondary beams in the vicinity of 78Ni at 250 MeV per nucleon were produced by in-flight fission of 238U primary beam at the energy of 345 MeV per nucleon with a 9Be production target. The cocktail beams were separated and identified event-by-event by BigRIPS and bombarded on another 9Be reaction target with a thickness of 6.8 mm. Reaction residues were analyzed by the ZeroDegree Spectrometer. The figure shows a summary of the experimentally obtained one-proton removal cross sections (σ-1p) compared with empirical theoretical calculations. These results behave even-odd staggering, which is assumed to be affected by neutron separation energies in the ablation process. The calculation with INCL+Abla07 reproduced the trends of experimental results very well, except for σ-1p(79Cu). The experimental σ-1p(79Cu) was much smaller than the calculation value. In this contribution, we will report the experimental results and discussions.

[258] Population of the Giant Pairing Vibration cross sections in the 12C(18O,16O)14C reaction. (16:00)

Presenter: VIGEZZI, Enrico

Several unsuccessful experimental attempts have been made [1], mostly through (p,t) reactions, to confirm the existence of the Giant Pairing Vibration (GPV), a collective L=0 mode predicted long ago to arise from the coherence of particle-particle excitations [2]. The GPV is expected to be populated by two-particle transfer reactions in the continuum. Its population and determination are difficult, due the existence of a substantial background associated with the excitation of other multipolarities, to poor Q-matching, and so on . Recently, signatures of the GPV were found in the energy spectra measured in the heavy ion, two-neutron transfer reaction ^{12}C(^{18}O,^{16}O)^{14}C (as well as in ^{13}C(^{18}O,^{16}O)^{15}C), measured at E_{lab}= 84 MeV and 275 MeV [3,4]. A broad bump was identified in ^{14}C at an excitation energy of about 17 MeV. We present the first calculations of the absolute cross section of this reaction in the region of the GPV, taking the continuum into account. They are based on theoretical strength functions associated with the two-neutron 0+ addition mode in ^{14}C, obtained discretizing the continuum in a large sphere by means of Dirichlet boundary conditions. Spurious discretisation effects are suppressed by taking an average over a set of sphere with different radii. Calculations have been made in the pp-RPA approximation and the response has been checked in ^{18}O, against calculations carried out in the framework of TDHF [5]. We have also carried out more elaborate calculations beyond pp-RPA, taking into account the effects of particle-vibration coupling. Based on such theoretical strength functions, we have evaluated the two-neutron transfer cross sections within the framework of second-order DWBA as a function of the ^{14}C(0+) excitation energy at the two experimental bombarding energies. Our results predict smaller cross sections than those attributed to the GPV in [3,4], though still in the observable range. References [1] M. Assié et al., Eur. Phys. J. A 55, 245 (2019) [2] R.A. Broglia and D.R. Bes, Phys. Lett. B 69, 129 (1977) [3] F. Cappuzzello et al., Nat. Comm. 6, 6743 (2015) [4] F. Cappuzzello et al., Eur. Phys. J. A 57, 34 (2021) [5] B. Avez et al., Phys. Rev. C 78 (2008) 044318

Coffee Break - Facultad de Ciencias de la Comunicación (16:20 - 16:50)

THU4 - Facultad de Ciencias de la Comunicación (16:50 - 18:10)

-Conveners: Filomena Nunes

[256] Two-neutron transfer: shape phase transitions and coexistence (16:50)

Presenter: LAY VALERA, José Antonio

A crucial problem in Physics is the study of Quantum Phase transitions. In nuclei, one finds shape phase transitions along isotopic chains where the nuclei change for example from a spherical ground state to a prolate one as long as we increase the number of neutrons above a certain critical value. This situation is usually studied in terms of energy ratios of the excited states and B(E2) values but it has been also found that two-neutron transfer reactions are sensitive to the phase transitions through two-neutron intensities, as calculated for example in the framework of the Interacting Boson Model [1-3]. Alternatively, one can find the same change in the shape of the ground state in a scenario different from the standard Quantum Shape Phase Transition. This is the case of shape coexistence, where a progressive mixing of the two phases can produce a sudden change in the dominant shape of the ground state. Recently, we have been studying the possibility of distinguishing these two scenarios through two-neutron transfer reactions [4,5]. We perform second-order DWBA calculations along two different cases. In the Samarium isotopic chain, we calculate transfer cross section from the two-neutron intensities calculated in the IBM model [1,6]. In the Zirconium isotopic chain, two-neutron amplitudes calculated in Monte Carlo Shell Model framework from T. Togashi and collaborators [7] are considered. Comparison with experimental data in the Samarium case [8] is consistent with a shape-phase transition, as expected. On the contrary, structure calculations for the Zirconium clearly show a shape coexistence. Two-neutron transfer cross sections reproduce the available experimental data [9] and exhibit a distinctive pattern distinguishable from a shape phase transition. Unfortunately, experimental data is not available in the relevant isotopes. [1] R. Fossion, C. E. Alonso, J. M. Arias, L. Fortunato, and A. Vitturi, Phys. Rev. C 76, 014316 (2007). [2] Y. Zhang and F. Iachello, Phys. Rev. C 95, 034306 (2017). [3] J.E. Garcia-Ramos; J.M. Arias, and A. Vitturi, 2020, Chinese Physics C 44: 124101 [4]A. Vitturi, L. Fortunato, I. Inci, and J. A. Lay, JPS Conf. Proc. 23, 01201 (2018). [5] J. A. Lay et al., arXiv:1905.12976 [6] P. Jodidar et al., In preparation. [7] T. Togashi et al., Phys. Rev. Lett. 117, 172502 (2016). [8] J. H. Bjerregaard. O. Hansen, O. Nathan and S. Hinds, Nucl. Phys. 86, 145 (1966). [9] E.R. Flynn, J.G. Beery, and A.G. Blair, Nucl. Phys. A 218, 285 (1974)

[257] Nuclear Josephson-like γ-emission (17:10)

Presenter: BARRANCO, Francisco

Nucleon pair transfer processes between superfluid nuclei in heavy ion reactions are considered as possible analogues of the transfer of Cooper pairs [1] of electrons through Josephson Junctions (JJ) [2]. A particular signature of this analogy concerns the dependence of absolute pair transfer cross sections on the number of transferred pairs [3-11]. In this contribution we present a novel approach to the study of the above analogy, based on the alternating current (ac) Josephson effect and associated electromagnetic radiation emitted in the process (see e.g. [12] and references therein; see also [13]), for which the consideration of one nuclear Cooper pair transfer, together with the corresponding one-nucleon transfer process, leads to a direct identification of the nuclear Josepson-like effect. It is based on the nuclear Cooper pair coherence length and on the γ-radiation emitted in the transfer process. Based on the seminal work of Montanari et al. ([14, 15]; see also [16]) carried out at the Laboratori Nazionali di Legnaro (LNL), where the absolute transfer differential cross sections of the reactions 116Sn +60Ni→62Ni+ 114Sn and 116Sn+60Ni→61Ni+115Sn at a large variety of bombarding energies, from above the Coulomb barrier to well below it have been measured and analyzed in detail (G. Pollarolo) in terms of the semiclassical approximation and of microscopically calculated optical potential based on this last reaction formfactors, we will present predictions of the γ-angular distributions, analyzing powers and strength functions ([17, 18, 19, 20, 21]; see also [22]). In this work we implement the quantum mechanical description of the coupling of the electric dipole associated with the (2n)-transfer reaction process, establishing the connection between the dynamics of the collision process and the number and energy dependence of the emitted γ photons, thus providing a robust quantitative signature of the (ac) Josephson-like nature of the phenomenon. Two important quantities emerge as conserved properties: the Cooper pair coherence length, and the length and orientation of the effective dipole associated with the two transferred neutrons. We will also comment on a most important result of our collaboration with the LNL (L. Corradi and S. Szilner), namely the recently approved by the PAC committee with high priority [23, 24], of the first experiment specifically dedicated to test our predictions. [1] L. N. Cooper. Phys. Rev., 104:1189, 1956. [2] B. D. Josephson. Phys. Lett., 1:251, 1962. [3] V. I. Goldanskii and A. I. Larkin. Soviet Physics JETP, 26:617, 1968. [4] K. Dietrich. Physics Letters B, 32(6):428, 1970. [5] K. Hara. Physics Letters B, 35:198, 1971. [6] K. Dietrich, K. Hara, and F. Weller. Phys. Lett. B, 35:201, 1971. [7] M. Kleber and H. Schmidt. Zeitschrift f¨ur Physik, 245:68, 1971. [8] H. Weiss. Phys. Rev. C, 19:834, 1979. [9] W. von Oertzen and A. Vitturi. Reports on Progress in Physics, 64:1247, 2001. [10] R. A. Broglia and A. Winther. Heavy Ion Reactions. Westview Press, Boulder, CO., 2004. [11] D. M. Brink. In Jose Miguel Arias, María Isabel Gallardo, and Manuel Lozano, editors, Nuclear Physics at the Borderlines, page 15, Berlin, Heidelberg, 1992. Springer Berlin Heidelberg. [12] P. E. Lindelof. Rep. Prog. Phys., 44:60, 1981. [13] A. Bohr and O. Ulfbeck. In First Topsøe summer School on Superconductivity and Workshop on Superconductors, Roskilde, Denmark Riso/M/2756, 1988. [14] D. Montanari, et al. Phys. Rev. Lett., 113:052501, 2014. [15] D. Montanari, et al. Phys. Rev. C, 93:054623, 2016. [16] Szilner, S. et al. EPJA Web of Conferences, 223:01064, 2019. [17] G. Potel, F. Barranco, E. Vigezzi, and R. A. Broglia. Phys. Rev. C, 103:L021601, 2021. [18] R. A. Broglia, F. Barranco, G. Potel, and E. Vigezzi. Nuclear Physics News, 31, No 4:24, 2021. [19] R. A. Broglia, F. Barranco, G. Potel, and E. Vigezzi. arxiv.2202.13193 [nuclth], 2022. [20] R. A. Broglia, F. Barranco, G. Potel, and E. Vigezzi. arxiv.2103.13536v3 [nucl-th], 2022. [21] R. A. Broglia, F. Barranco, L. Corradi, G. Potel, S. Szilner, and E. Vigezzi. (to be published), 2022. [22] P. Magierski. Physics, 14:27, 2021. [23] L. Corradi et al. Search for a Josephson-like effect in the 116Sn+60Ni system, proposal PRISMA+AGATA experiment (spokepersons: L. Corradi and S. Szilner) . 2022. [24] L. Corradi. Result of the evaluation of the Program Advisor Committe-LNL meeting, February 21-24. Private communication, 2022.

[186] Informing direct neutron capture for the weak r-process via the (d,p) reaction with 84Se beams at two energies (17:30)

Presenter: CIZEWSKI, Jolie

Neutron capture reactions on nuclei near neutron shell closures predominantly proceed via direct-semi-direct processes that require knowledge of the neutron spectroscopic strengths of specific excitations. Understanding neutron capture on neutron-rich nuclei near N=50 is also important for understanding the synthesis of nuclei via a weak r-process [1]. Of particular interest is neutron capture on the N=50 isotone 84Se. We measured the (d,p) reaction with 45 MeV/u rare isotope 84Se beams at the National Superconducting Cyclotron Laboratory (NSCL) where reaction protons were measured in the Oak Ridge Rutgers University Barrel Array (ORRUBA) of position-sensitive silicon strip detectors in coincidence with beam-like recoils analyzed with the S800 magnetic spectrograph. The results from this measurement were combined with previous measurements [2] at 4.5 MeV/u to constrain the single particle asymptotic normalization coefficient (spANC) and therefore the spectroscopic factors for the ground 5/2+ state (2d5/2) and first excited ½+ state (3s1/2) were deduced with uncertainties dominated by statistics rather than uncertainties in the bound state potential, using methods from previous studies with stable 86Kr beams [3]. The spectroscopic factors for these 5/2+ and 1/2+ states were used to deduce direct-semi-direct neutron capture cross sections as a function of neutron energy. This collaboration is also approved to measure the (d,p□) reaction with 80Ge beams at the Facility for Rare Isotope Beams (FRIB) at the S800 using ORRUBA coupled to GRETINA to realize GODDESS (ORRUBA Gamma Array: Dual Detectors for Experimental Structure Studies). The 80Ge(d,p) reaction has previously been measured at 3.9 MeV/u [4]. The approved experiment would not only inform DSD capture on a nucleus important in understanding weak r-process nucleosynthesis but would also inform the competition between DSD and neutron capture that proceeds via a compound nucleus. The present talk would summarize the results from the 84Se measurements, including the DSD capture results, and the status of mounting GODDESS at FRIB for the 80Ge measurement. This work is supported in part by the National Science Foundation and the U.S. Department of Energy. [1] R. Surman et al., AIP Advances **4**, 041008 (2014). [2] J.S. Thomas et al., Phys. Rev C **76**, 044302 (2007) [3] D. Walter et al., Phys. Rev. C **99**, 054625 (2019). [4] S. Ahn et al., Phys. Rev. C **100**, 044613 (2019)

[225] Applications of ab initio nuclear theory to astrophysics reactions (17:50)

Presenter: NAVRATIL, Petr

A realistic description of atomic nuclei, in particular light nuclei characterized by clustering and low-lying breakup thresholds, requires a proper treatment of continuum effects. We have developed an approach, the No-Core Shell Model with Continuum (NCSMC) [1,2], capable of describing both bound and unbound states in light nuclei in a unified way. With chiral two- and three-nucleon interactions as the only input, we are able to predict structure and dynamics of light nuclei and, by comparing to available experimental data, test the quality of chiral nuclear forces. We will discuss applications of NCSMC to nuclear reactions important for astrophysics and present results for the proton radiative capture reactions the 7Be(p,γ)8B [3] and 11C(p,γ)12N radiative capture. The 7Be(p,γ)8B reaction plays a role in Solar nucleosynthesis and Solar neutrino physics and has been subject of numerous experimental investigations. We will also highlight our recent calculations hinting at a possible near-threshold S-wave resonance in 6He+p [4] that might have implications for astrophysics. Experimental investigation of resonant 6He scattering on protons is planned at TRIUMF. Supported by the NSERC Grants No. SAPIN-2016-00033 and SAPPJ-2019-00039 and by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Work Proposals No. SCW1158 and No. SCW0498. TRIUMF receives federal funding via a contribution agreement with the National Research Council of Canada. This work was prepared in part by LLNL under Contract No. DE-AC52-07NA27344. Computing support came from an INCITE Award on the Summit supercomputer of the Oak Ridge Leadership Computing Facility (OLCF) at ORNL, from Westgrid and Compute Canada, and from the LLNL institutional Computing Grand Challenge Program. [1] S. Baroni, P. Navratil, and S. Quaglioni, Phys. Rev. Lett. 110, 022505 (2013); Phys. Rev. C 87, 034326 (2013). [2] P. Navratil, S. Quaglioni, G. Hupin, C. Romero-Redondo, A. Calci, Physica Scripta 91, 053002 (2016). [3] K. Kravvaris, P. Navratil, S. Quaglioni, C. Hebborn, G. Hupin, arXiv: 2202.11759. [4] M. Vorabbi, P. Navratil, S. Quaglioni, G. Hupin, Phys. Rev. C 100, 024304 (2019).

Conference Dinner - Facultad de Ciencias de la Comunicación (20:00 - 22:00)

Friday, 1 July 2022

FRI1 - Facultad de Ciencias de la Comunicación (09:00 - 10:40)

-Conveners: Tomohiro Uesaka

[223] Direct reactions studies with the AT-TPC (09:00)

Presenter: BAZIN, Daniel

The Active Target Time Projection Chamber (AT-TPC) has been used successfully in a number of pioneering experiments ranging from resonant scattering to high energy charge exchange. The key experimental factor common to these experiments is the detection of low energy recoils in a thick target without loss of resolution. The high luminosity provided by this methodology extends the scientific reach of rare isotope facilities by enabling the use of reaction tools at lower intensities compared with passive target setups. This talk will present an overview of the recent accomplishments of the AT-TPC, with an emphasis on the latest experiment aimed at the commissioning of transfer reactions using the ^{10}Be(d,p)^{11}Be reaction in inverse kinematics. The secondary goal of this experiment is to verify the parity of the 3.41 MeV J=3/2 resonance in ^{11}Be. The AT-TPC was filled with 600 Torr of pure deuterium gas and placed in SOLARIS while a ^{10}Be beam was accelerated to 10 MeV/u by the ReA6 linac of FRIB. Preliminary results on the (d,p) transfer reaction channel obtained with an average of 1000 beam particles per second will be presented.

[261] Peeling off Neutrons: Using Fragmentation Reactions to Measure the Neutron Skin (09:20)

Presenter: JEDELE, Andrea

By studying the neutron skin thickness across the Sn isotopic chain, one can gain a rich insight into the slope of the density dependence of the symmetry energy. A novel method using the total neutron-removal cross section (□□N) has been shown to be highly sensitive to the slope, with a 1% change in □□N corresponding to a variation of L=±5 MeV. Experiments have been performed at GSI at 400<E/A (MeV/nuc)<900 with 120,124,128,132,134Sn projectiles on p and 12C targets.

[240] Weisskopf units for neutron-proton pair transfers* (09:40)

Presenter: MACCHIAVELLI, Augusto

Two-neutron transfer reactions such as (p,t) and (t,p) have provided a unique tool to understand neutron pairing correlations in nuclei [1]. Based on the formal analogy between pairing distortions and quadrupole shape fluctuation [1], where an important measure of collective effects is provided by the B(E2) transition probabilities, one can associate a similar role to the transition operators <f | a+ a+ | i> and <f | a a | i> in the two-particle transfer mechanism between the initial |i> and final |f> states. To study np correlations in N=Z nuclei, it thus seems natural to consider the transfer of an np pair from even-even to odd-odd self-conjugate nuclei as a sensitive probe, and of the possible direct reactions we could envision, the (3He,p) and (p,3He) are perhaps the best choices since both isoscalar and isovector transfers are allowed. In this work [2], we introduce the concept of neutron-proton np two-particle units (or np Weisskopf units) to be used in the analysis of the (3He,p) and (p,3He) reactions along the N=Z line. These are presented for the conditions relevant to the (n,l,j) orbits expected from 16O to 100Sn. As are the cases of the Weisskopf units for electromagnetic transitions [3] and the two-particle units relevant for two-neutron transfers [4], the np-WU's will provide a simple, yet robust, measure to assess isoscalar and isovector pairing collectivity. * This work is based on the research supported in by the Director, Office of Science, Office of Nuclear Physics, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231 (LBNL), by the Spanish Ministerio de Ciencia, Innovación y Universidades and FEDER funds under project FIS2017-88410-P, and by the U.S. National Science Foundation (NSF) under Cooperative Agreement No. PHY-1565546. Y.A. acknowledges the support by the Spanish Ministerio de Economía y Competitividad through the Programmes "Ramón y Cajal" with the grant number RYC2019-028438-I [1] R.A. Broglia, O. Hansen and C. Riedel, Adv. Nucl. Phys. Vol 6 (1973) 287. [2] J.A.Lay, Y.Ayyad and A.O.Macchiavelli, Phys. Lett. B 824 (2022) 136789. [3] V.F. Weisskopf, Phys. Rev. 83 (1951) 1073. [4] R.A. Broglia, C. Riedel and T. Udagawa, Nuclear Physics A184 (1972) 23.

[272] Experimental study of many-neutron systems 7He and 7H (10:00)

Presenter: HUANG, Siwei

Structure of neutron-rich nuclei located around the neutron drip line and their multi-neutron correlations have been among the hottest topics in nuclear physics. The properties of these nuclei serve as an important benchmark of modern nuclear theories. Moreover, such unstable systems could decay via emission of multiple neutrons. These constituent neutrons, when detected, will provide direct information on the multi-neutron correlations, which is crucial for understanding the exotic phenomena towards the neutron drip line and the properties of neutron stars [1-2]. We carried out a new experimental study of ^{7}He and ^{7}H at RIKEN RIBF facility by directly detecting their decay neutrons. The three-neutron-unbound ^{7}He (excited state) and four-neutron-unbound ^{7}H were populated by using the quasi-free one-neutron knock out reaction ^{8}He(p, pn)^{7}He and one-proton knock out reaction ^{8}He(p, 2p)^{7}H{^{3}H+4n}, respectively. The momentum of the charged fragments was analyzed by the SAMURAI spectrometer [3] and the associated detectors. Taking advantage of the state-of-the-art neutron detector array combining the NeuLAND demonstrator from GSI and the existing NEBULA array, the decay neutrons can be detected. In this talk, some preliminary results will be presented. [1] F. Miguel Marqués, Jaume Carbonell, Eur. Phys. J. A 57, 105 (2021) [2] P. B. Demorest, et al., Nature 467, 1081–3 (2010) [3] T. Kobayashi, et al., Nucl. Instrum. Methods Phys. Res., Sect. B 317, 294 (2013)

[203] Shell evolution from N = 34 towards N = 40: first 2^{+} state in ^{52}Ar and the first excited 0^{+} state in ^{54}Ca (10:20)

Presenter: LIU, Hongna

Shell gaps represent the backbone of the nuclear structure and are a direct fingerprint of the in-medium many-body interactions. The nuclear shell structure is found to change, sometimes drastically, with the number of protons and neutrons, revealing how delicate the arrangement of interacting nucleons is. Recent experimental evidence favors a new doubly-magic nucleus ^{54}Ca with a neutron subshell closure at N = 34 [1-3], although the systematics of E(2$^{+}_{1}$) [4-5]and B(E2; 0$^{+}_{1}$ $\rightarrow$ 2$^{+}_{1}$) [6,7] in Ti and Cr isotopes does not show any evidence for the N = 34 magicity. To study how the N = 34 subshell evolves below Z < 20 towards more neutron-rich systems, we measured the low-lying structure of ^{52}Ar using the ^{53}K(p, 2p) one-proton removal reaction at □210 MeV/u at the RIBF facility [8]. The 2$^{+}_{1}$ excitation energy is found at 1656(18) keV, the highest among the Ar isotopes with N > 20. This result is the first experimental signature of the persistence of the N = 34 subshell closure beyond ^{54}Ca. Shell-model calculations with phenomenological and chiral-effective-field-theory interactions both reproduce the measured 2$^{+}_{1}$ systematics of neutron-rich Ar isotopes and support an N = 34 subshell closure in ^{52}Ar. For the doubly magic nucleus ^{54}Ca, several state-of-the-art nuclear structure calculations predict that it has a bond first excited 0^{+} state but with very different excitation energies [9-10]. In particular, shell model calculations with the effective LNPS-U interaction [11] predict significant intruder configurations with rather strong correlations in the first excited 0^{+} state in ^{54}Ca, and suggest that its excitation energy can provide information on correlations of the gds orbitals lying above the N = 34 subshell closure, which will constrain the predictions for ^{60}Ca (N = 40) and the dripline of the Ca isotopes. We, therefore, propose to search for the first excited 0^{+} state in ^{54}Ca using ^{56}Ti(p, 3p) reactions using missing-mass and in-beam γ spectroscopy, which is approved by the NP-PAC committee at RIKEN. To summarize, to explore the shell evolution from N = 34 towards N = 40, we measured the first 2^{+} state in ^{52}Ar and will search for the first excited 0^{+} state in ^{54}Ca. References [1] D. Steppenbeck et al., Nature 502, 7470, 207 (2013). [2] S. Chen et al., Phys. Rev. Lett. 123,142501(2019). [3] S. Michimasa et al. Phys. Rev. Lett. 121, 022506 (2018). [4] H. Suzuki et al., Phys. Rev. C 88, 024326 (2013). [5] S. Zhu et al., Phys. Rev. C 74, 064315 (2006). [6] D.-C. Dinca et al., Phys. Rev. C 71, 041302(R) (2005). [7] A. Bürger et al., Phys. Lett. B 622, 29 (2005). [8] H. N. Liu et al., Phys. Rev. Lett. 122, 072502 (2019). [9] J. D. Holt et al., Phys. Rev. C 90, 024312 (2014). [10] G. Hagen et al., Phys. Rev. Lett. 109, 032502 (2012). [11] F. Nowacki and A. Poves, private communication (2021).

Coffee Break - Facultad de Ciencias de la Comunicación (10:40 - 11:20)

FRI2 - Facultad de Ciencias de la Comunicación (11:20 - 13:00)

-Conveners: Maria Colonna

[181] Reaching interesting reactions cross-sections by measuring radioactive recoils with AMS technique: the successful cases of 10Be, 14C and 26Al. (11:20)

Presenter: ACOSTA SANCHEZ, Luis Armando

The present work is devoted to show a successful alternative method to measure specific direct reaction cross sections, related to the production of a particular radioactive recoil. The method is based on the production of a relatively small yield of a radioactive nucleus, assisted by ion and/or low-neutron irradiation, fixing a specific reaction at an interesting low energy. The irradiated material is later radiochemically processed to be introduced in a special cathode which will be inserted in a negative ion source, searching the production of a radioactive low energy beam, in order to be studied with Accelerator Mass Spectrometry (AMS) [1,2]. The result is the measurement of a total amount of the radioactive specie as a function of a stable nuclei, which as well is necessarily part of the material in the cathode. The ratio of the radioactive/stable beams measured with AMS may be later translated in the total cross section of the initial reaction, allowing a very precise measurement of reactions that normally imply a complicate access when they are tried in conventional modes. Most of the reactions involving 10Be, 14C and 26Al at low energies show a worth interest, particularly in Nuclear Astrophysics. The relatively long half-live of such nuclei, make them good candidates to be approached by using AMS technique. In this work the cross sections measured for 9Be(n,ɣ)10Be, 14N(n,p)14C and 13C(n,γ)14C at 25 meV are presented [3], as well as the preliminary results for the 26Al yield of the 28Si(d,α)26Al reaction (1.0 - 4.8 MeV) [4-6]. Details of the preparation for 25Mg(p,γ)26Al at 418 keV measurement, are as well presented here. The experimental results reported shown an acceptable agreement with calculations found in the literature, demonstrating the success of this alternative method [7]. This work has been partially funded by CONACyT 315839 and PAPIIT-DGAPA IN107820 and AG101120. [1] C. Solís, et. al., Nucl. Inst. Meth. Phys. B 331, (2014). [2] A. Arazi, et. al., Phys. Rev. C 74, 025802 (2006). [3] D.J. Marín-Lámbarri, et al., Phys. Rev. C 102 044601 (2020). [4] V. Araujo-Escalona, et. al., Phys. Proc., 90, (2017). [5] L. Acosta, et. al., Eur. Phys. J. Web. of Conf. 165, 01001 (2017). [6] G. Reza, et al., Eur. Phys. J. Plus, 135, 899 (2020). [7] L. Acosta, et. al., Eur. Phys. J. Web of Conf. 252, 05003 (2021)

[285] α-cluster structure of 18Ne (11:40)

Presenter: BARBUI, Marina

We studied alpha-clustering in 18Ne and compared it with alpha-clustering in the mirror nucleus 18O. To the best of our knowledge, this is one of the first detailed experimental studies of clustering phenomena in mirror systems. The excitation function for α+14O resonant elastic scattering was measured in the energy range from 7.5 to 17 MeV. Measurements were performed at the Texas A&M University Cyclotron Institute using TexAT [1] active target detector. Detailed spectroscopic information on the populated excited states in 18Ne was obtained from the R-matrix analysis and compared to similar data on the states in 18O reported by Avila et al. [2]. A good correspondence between the levels in 18O and 18Ne is observed, as is expected due to isospin symmetry. We carried out an extensive shell model analysis based on the configuration interaction technique [3]. Comparing experimental results with theory, we notice a remarkably good agreement between the predicted and observed states allowing further configurational categorization of the strong cluster states. There is also an indication that the super-radiance mechanism is essential in generating clustering in 18Ne and 18O. Our data indicate that, in mirror states, the state with the largest alpha partial width is also the one with the largest spectroscopic factor. Super-radiance may, in principle, explain this trend. Experimental results and a comparison with theory will be presented. [1] E. Koshchiy, et al., Nucl. Inst. and Methods in Physics Research A 957, 163398 (2020). [2] M. L. Avila et al., Phys. Rev. C 90, 024327 (2014). [3] K. Kravvaris, A. Volya, Phys. Rev. C 100, 034321 (2019).

[267] Structural evolution of neutron-rich calcium isotopes (12:00)

Presenter: CHEN, Sidong

The studies in the past decades revealed that the canonical magic numbers established for stable nuclei may not extend their universality to exotic nuclei, while new magic numbers emerge in some nuclei [1]. These new features often can be traced back to certain characteristic mechanisms of nuclear forces [1,2], for instance, the tensor force, which can vary the spin-orbit energy splitting and result in changes of shell structures. Discovering and interpreting these new features provide a fundamental test for the understanding of nuclear forces, and play a key role in the prediction of the dripline in the Segrè chart of nuclides. The calcium isotopes, with 20 protons (Z=20) forming the closed proton shell, exhibit a high sensitivity of the shell evolution according to the neutron number. In the neutron-rich side, signatures of new magic numbers or sub-shell closures have been found at N=32 and 34 [3,4], and interpreted as a consequence of the absence of a tensor attraction between valence protons and neutrons. For the N=34 sub-shell closure, the first experimental evidence was presented by the measured large E(2^+_1) in ^{54}Ca [4]. It was then supported by the mass measurements of $^{55-57}$Ca isotopes [5]. Following these studies, we further investigated the nature of N=34 sub-shell closure by knockout reactions, and the structural evolution of calcium isotopes above the N=34 sub-shell closure. The experiments were carried out at RIBF using the intense radioactive beams provided by the BigRIPS separator. A thick liquid hydrogen target of the MINOS device was used to induce the knockout reactions, and the DALI2$^+$ high-efficiency array was arranged around the target for the detection of de-excitation γ rays of reaction products. The reaction products were identified by the SAMURAI spectrometer. The exclusive cross sections and momentum distributions of the ^{54}Ca(p,pn)^{53}Ca reaction channel were measured in the experiment, which provide access to the neutron occupation number of the ^{54}Ca ground state and spin parity of the ^{53}Ca final states [6]. Moving beyond the N=34 sub-shell closure, the first spectroscopy measurements of ^{56,58}Ca were performed. The obtained results are confronted with state-of-the-art *ab initio* and shell-model calculations, permitting a sound prediction on the structure of ^{60}Ca and the dripline of calcium isotopes. In this talk, the physics interests of the calcium isotopes, the descriptions of the experiments and the discussions of the results shall be given in details. [1] T. Otsuka et al., Rev. Mod. Phys. **92**, 015002 (2020). [2] O. Sorlin and M.-G. Porquet, Phys. Scr. **T152**, 014003 (2013). [3] F. Wienholtz et al., Nature, **498**, 346, (2013). [4] D. Steppenbeck et al., Nature, **502**, 207, (2013). [5] S. Michimasa et al., Phys. Rev. Lett. **121**, 022506 (2018). [6] S. Chen et al., Phys. Rev. Lett. **123**, 142501 (2019).

[270] Exploring the clustering in neutron-rich Be and B isotopes by reactions of 9Li beam on LiF target (12:20)

Presenter: VUKMAN, Nikola

A promising way to study the clustering and molecular like structures, even in neutron-rich light nuclei, is to explore the sensitivity of transfer reactions to the structure of the nuclei in the reaction entrance channel. Evolution of the clustering phenomena with the addition of neutrons in beryllium isotopes, from the α-α two-center clustering in ^{8}Be to the molecular like α-Xn-α structures in ^{10}Be and ^{12}Be $[1,2]$, is an important benchmark to our understanding of the nuclear structure. Likewise, for neutron-rich boron isotopes the lithium-helium clustering is proposed to exist at higher excitation energies $[3]$, but still needs strong experimental investigation, as there are only a few experimental studies available to confirm the claim $[4,5]$. With the aim to study these structures experiment S1620 was performed at the ISAC-II facility at TRIUMF, using the ^{9}Li beam and LiF target. Large solid angle array, comprised of six wedge shaped telescopes, each having 65 μm thick ΔE and 1.5 mm thick E detector, both SSSSD, arranged in "lampshade" geometry, was used and the reaction products were identified using the standard ΔE-E method. Many interesting decay channels of the neutron-rich light nuclei were populated in this reaction, the ^{12}Be and ^{13}B being preeminent as they could have been produced by either triton or alpha transfer to the ^{9}Li beam. The observed cluster decays of the ^{10}Be excited states to the ^{4}He+^{6}He and ^{4}He+^{6}He* pairs, the ^{12}Be decays to the ^{4}He+^{8}He, ^{6}He+^{6}He and ^{6}He+^{6}He* pairs, together with the cluster decays of the ^{13}B excited states to the ^{9}Li+^{4}He and possibly ^{7}Li+^{6}He pairs will be presented and discussed. Results confirm known cluster states and provide strong indications for previously unobserved decay channels and cluster states, strongly supporting the existence of exotic clustering in these nuclei. BIBLIOGRAPHY: $[1]$ M. Freer, H. Horiuchi, Y. Kanada-En'yo, D Lee, U.G. Meißner: Reviews of Modern Physics 90 (3), (2018) 035004 $[2]$ Z.H. Yang et al. Phys. Rev. C, 91, (2015) 024304 and references therein $[3]$ Y. Kanada-En'yo, Y. Kawanami, Y. Taniguchi, M. Kimura; Prog.Theor.Phys. 120, 5, (2008) 917–935 $[4]$ A. Di Pietro et al. J. Phys. Conf. Ser. 966 (2018) 012040 $[5]$ R. J. Charity et al. Phys. Rev. C 78, (2008) 054307

[233] Testing three-body forces in the oxygen region via lifetime measurements (12:40)

Presenter: ZANON, Irene

The investigation of the three-body forces influence in the structure of light nuclei has gained a lot of interest in recent years. In this context, the oxygen isotopic chain is a perfect playground. In fact, the introduction of three-body forces in the interaction explained the change in neutron shell closure from $\nu d_{3/2}$ ($N=20$) to $\nu s_{1/2}$ ($N=16$), as observed experimentally. While the importance of three-body forces in this region is established, their contribution has yet to be quantified. The ^{20}O represents an interesting study case. In fact, the 2^+_2 and 3^+_1 states are based on a mixed $(d_{5/2})^3(s_{1/2})^1$ neutron configuration. These orbitals are influenced by the contribution of 3N forces. Hence, electromagnetic properties of the 2^+_2 and 3^+_1 states, such as excitation energies, branching ratios and reduced transition probabilities, provide meaningful information on the position of the $d_{5/2}$ and $s_{1/2}$ orbitals. An experiment aimed at measuring the lifetime of these states was performed at GANIL (France). The ^{20}O was populated via a (d,p) reaction, using a post-accelerated radioactive beam of ^{19}O provided by the SPIRAL complex and a deuterated polyethylene target deposited on a gold degrader. The beam-like and target-like partners were detected using the VAMOS spectrometer and the MUGAST array, respectively. The chosen reaction allowed the reconstruction of the excitation energy spectrum of the nucleus of interest from the information on the detected protons, as well as the use of selective gates to perform spectroscopy measurement of weakly populated states. Finally, the γ rays emitted by the ^{20}O were detected by the AGATA array at backward angles. The level scheme of the ^{20}O, obtained from γ-particle coincidence measurements, was reconstructed. Then, the lifetimes of the 2^+_2 and 3^+_1 states were measured using the Doppler-Shift Attenuation method. In particular, the experimental lineshapes of the $2^+_2 \to 2^+_1$ and $3^+_1 \to 2^+_1$ transitions at 2396 keV and 3552 keV respectively have been compared to realistic Monte Carlo simulations, optimized in order to reduce the sources of systematic errors. In this contribution, the results of the γ-particle spectroscopy and the lifetime measurements of the 2^+_2 and 3^+_1 states is be presented. A preliminary interpretation of the results is also presented.

Lunch break - Facultad de Ciencias de la Comunicación (13:00 - 14:40)

Concluding Remarks - Facultad de Ciencias de la Comunicación (14:40 - 15:30)