Instituto de Estudos Avançados da Universidade de São Paulo

IV Workshop Internacional IEA sobre "the structure and reactions of exotic nuclei."

A estrutura e as reações de Núcleos Não Convencionais

Neste Workshop Internacional pretende-se reunir especialistas de renome no IEA para discutir os avanços recentes na física de núcleos ricos em nêutrons e prótons e analisar o papel destes sistemas fracamente ligados no processo de nucleossintese que envolve a captura lenta de nêutrons (slow nêutron capture, processo-s). A pesquisa mundial nesta área de física nuclear e' intensa e ha inúmeros centros dedicados a ela. Ha também planos para construir novos centros de grande porte como o FRIB nos EUA, FAIR na Alemanha, e outros. Nestes centros pretende-se ampliar a capacidade de produzir tais núcleos instáveis para estudá-los através das suas reações com núcleos estáveis em energias que variam de baixos valores, próximas das barreiras Coulombianas, onde efeito de túnel e' dominante, ate altos valores. O Workshop e' organizado pelo "Grupo de Astrofísica Não Convencional" do IEA.

Mahir Hussein

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Search for cluster states in 9Be through the 8Li(p, d) 7Li reaction

We report on a recent measurements of the (p, p), (p, α) and (p, d) reactions on 8Li at low energies [1]. The experiments were performed using a thick [CH2]n target and a radioactive 8Li beam available at the RIBRAS facility of S˜ao Paulo [2]. These experiments represent an upgrade of a previous experiment [3], where only the 8Li(p, α) 5He cross section was measured. The simultaneous measurement of the excitation functions and the comparison with previous direct 7Li(d, p) 8Li data allows the identification of resonances with cluster structures. The properties of these resonances will be determined by a R-matrix analysis [4]. [1] E. Leistenschneider et al., to be published [2] A. L´epine-Szily, R. Lichtenth¨aler, V. Guimar˜aes, Eur. Phys. J. A 50, 128 (2014) [3] D. R. Mendes et al., Phys. Rev. C 86, 064321 (2012) [4] P. Descouvemont and D. Baye, Rep. Prog. Phys. 73, 036301 (2010)

Search for cluster states in 9Be through the 8Li(p, d) 7Li reaction

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An Update on the recent developments of RIBRAS

S. Appannababu, R. Lichtenthäler, M. A. G. Alvarez, A.Lépine-Szily, K. C. C. Pires, U. U. da Silva, V. Scarduelli

With the advent of new radioactive ion beam facilities, It is possible to investigate the nuclear reaction studies with unstable projectiles. Reactions induced by radio active ion beams is one of the current interesting topics in nuclear physics, due to the observation of cluster structure and the weak breakup energies, when compared to the stable nuclei . RIBRAS (Radioactive Ion Beams in Brasil) is a twin solenoid radioactive ion beam facility at the University of Sao Paulo, which delivers secondary beams such as 6He, 8Li, 8B, 7Be with good intensities to perform nuclear physics experiments [1, 2]. In the past, several experiments on elastic scattering, alpha particle production, total reaction cross sections were studied on various targets of different masses [2]. A large production of alpha particles has also been observed in the reactions with 6He on several targets [3]. Recently, experiments were performed to study the resonant elastic scattering and resonant transfer reactions, using inverse kinematics and thick targets. We plan to install a small chamber at the end of the RIBRAS beam line, in order to detect the gamma rays in coincidence with the charged particles to study break up reaction dynamics. We will be presenting the recent experimental results on elastic scattering, alpha-particle production and total reaction cross sections, as well as the resonant elastic and transfer reactions. We also intend to discuss the recent developments on the design of a new chamber to detect the gamma rays in coincidence with the charged particles, along with the monte carlo simulations of the trajectories and the size of the beam spot in the newly planned chamber.

References:

1) R. Lichtenthäler et al., Eur. Phys. J. A 25 (2005) 733.
2) A. Lépine-Szily, R. Lichtenthäler, and V. Guimarães. Eur. Phys. J. A 50, 128 (2014). 3) P. N. De Faria et al., Phys. Rev. C 82, 034602 (2010).

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Towards a more complete description deuteron-induced reactions

Deuteron-induced reactions are being used to produce medical radioisotopes [1] and as surrogates to other reactions (see review [2] and references therein), among recent applications. Although they have been studied for decades [3-6], their complexity continues to make their theoretical description challenging. The direct reaction mechanism is a major contributor to the reaction cross section due to the low binding energy of the deuteron. Competition between elastic breakup, absorption of only a neutron or a proton (stripping and inelastic breakup) and absorption of the deuteron must be taken into account to determine the formation or not of a compound nucleus and its subsequent decay. The inelastic breakup reactions – those in which either only a neutron or a proton is absorbed – are particularly complex, as they form compound nuclei with a wide range of excitation energies and angular momenta. We present the results of a theoretical study of elastic and inelastic deuteron breakup for a large selection of targets at incident deuteron energies below 100 MeV. We use the zero-range post-form DWBA approximation to calculate the elastic breakup cross section [3,4] and its extension to absorption channels to calculate the inelastic breakup cross sections [5,6]. We look in detail at the extent to which our DWBA is capable of describing the inclusive breakup cross sections. We also discuss the regularities and ambiguities in our results, as well as the irregularities in the inelastic breakup energy and angular momentum distributions that complicate their substitution by a smooth distribution obtained from systematics.

References

[1] E.Betak et al, Technical Reports Series 473, "Nuclear Data for the Production of Therapeutic
Radionuclides", IAEA, Vienna, Austria, 2011, ISBN 978-92-0-115010-3.
[2] J.E. Escher, J.T. Burke, F.S. Dietrich, N.D. Scielzo, I.J. Thompson, and W.Younes, Rev. Mod. Phys. 84,
353 (2012).
[3] G. Baur and D. Trautmann, Phys. Rep. 25, 293 (1976).
[4] G. Baur, F. Rösel, D. Trautmann and R. Shyam, Phys. Rep. 111, 333 (1984).
[5] A. Kasano and M. Ichimura, Phys. Lett. B115, 81 (1982).
[6] N. Austern, Y. Iseri, M. Kamimura, M. Kawai, G. Rawitscher and M. Yahiro, Phys. Rep. 154, 125 (1987).

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The neutron within the deuteron and neutron-induced reactions

Neutron induced reactions are of great relevance for nuclear astrophysics (I.e., r-processes), advanced fuel cycles, stockpile stewardship, and applications of nuclear science. However, it is quite difficult to perform direct measurements of neutron capture by nuclei. Moreover, theoretical models, mostly based on statistical theories often have difficulties reproducing experimental data. An alternative to direct experiments with free neutrons is the use of deuterons as a surrogate to induce neutron capture on a target. In this talk I will discuss benchmark calculations of (d,p) reactions and in particular I will discuss the reactions on 135Xe which has a neutron capture cross section of 6 million barns.

The quest for the origin of the elements

Nuclear astrophysics is a vibrant research field, with a close connection to numerous recent discoveries and predictions in astrophysics and cosmology. It deals with nuclear reactions which generate different states of matter, energy which powers the stars and the elements we observe in the Universe today, remnants of the Big Bang and stellar nucleosynthesis. But the information on reactions of relevance for understanding cosmology and stellar evolution are difficult to extract directly in laboratory measurements at the small astrophysical energies. In recent years, new methods have been developed with a combination of progress in theory and new experimental techniques, which are the subject of this talk.

Carlos Bertulani
Texas- A&M Commerce

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"The BINGO Telescope: a new 21 cm window for exploring the Dark Universe and other astrophysics"

BINGO is a unique radio telescope designed to make the first detection of Baryon Acoustic Oscillations (BAO) at radio frequencies. This will be achieved by measuring the distribution of neutral hydrogen gas at cosmological distances using a technique called Intensity Mapping. Along with the Cosmic Microwave Background anisotropies, the scale of BAO is one of the most powerful probes of cosmological parameters, including dark energy.

The telescope will be built in a low RFI site in Northern Uruguay and located in a disused, open cast, gold mine. It will operate in the frequency range going from 0.96 GHz to 1.26 GHz, be of a twomirror compact range design with a 40 m diameter primary and have no moving parts. Such a design will give the excellent polarization performance and very low sidelobe levels required for intensity mapping. With a feedhorn array of 50 receivers, it will map a 15o declination strip as the sky drifts past the telescope. The partners in BINGO are Brazil, United Kingdom, Switzerland, Uruguay, China and Saudi Arabia.

Elcio Abdalla (IF-USP)

Effect of Coulomb breakup on the elastic cross section of 8B proton-halo projectile on the 208Pb heavy target

We investigate the role of the breakup channel in the elastic and breakup cross sections, in collisions of proton-halo nuclei. For this purpose, we perform continuum discretized couple channel calculations for the 8B +208 Pb system. We study also the individual contributions of the Coulomb and nuclear couplings to the cross sections. Polarization potentials for this reaction were also derived, using two options for the imaginary part of the optical potential, with long or short range. The effect of these short and long imaginary potentials on the breakup angular distributions are also investigated. To compare the effects of the breakup channel in proton-halo and neutro-halo nuclei, we perform calculations treating 8B as a 7B + n core-nucleon system, using an artificially low breakup threshold.

J.Lubian J. Rangel, L.F. Canto and P.R.S. Gomes

Reinterpreting the Energy-Dependence of the Optical Potential. L. C. Chamon and L. R. Gasques. (IF-USP)

In earlier works, we proposed a model for the nuclear potential of alpha-nucleus systems which is energy independent and has no adjustable parameters. This interaction has been successfully applied in the description of fusion, elastic and inelastic scattering data for many of those systems at the region of low energies. In the present work, we assume the same interaction as the bare potential to study the elastic scattering for 4He + 208Pb in a wide energy range. We demonstrate that the corresponding data set can be described if couplings to inelastic states with high excitation energy are explicitly considered through coupled-channel calculations.

L. C. Chamon (IF-USP)

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Imitations of Reduction Methods for Fusion and Total Reaction Cross Sections.

Very recently we have investigated the most frequently used methods to reduce fusion and total reaction excitation functions. These methods are widely used in the literature, especially to compare the cross sections of weakly and tightly bound systems, and then to find out the effects of the breakup of the weakly bound nuclei on these reaction processes. In the case of fusion excitation functions, we confirmed that the fusion function method is the only one that works very well, for any system at any energy regime. Regarding total reaction excitation functions, none of the methods was satisfactory. Their reduced reaction cross sections kept a strong dependence on the atomic and mass numbers of the collision partners. In the present work we make a revision of conclusions of almost twenty published papers on total reaction cross sections, when we find that several of them are not correct, since some of the effects described as owing to the breakup process are, in fact, consequences of the limitations of the reduction methods used. Then, possible general conclusions are also presented.

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Development of nuclear instrumentation for the Radioactive Ion Beams in Brazil (RIBRAS) facility.

A brief description of the Radioactive Ion Beams in Brazil (RIBRAS) facility will be presented, with emphasis to the new nuclear instrumentation, which are currently being developed and connected on the RIBRAS experimental program. RIBRAS system is based on two superconducting solenoids, installed along an experimental beam line connected to a Pelletron tandem accelerator of 8MV terminal voltage. After the second solenoid, an improvement of the secondary beam purity, up to 99%, can be obtained. Thus, a new reaction chamber, placed after the second solenoid, is being developed for exotic nuclei reaction measurements. Such chamber has been equipped with two rotating disks that support detectors and allow them to rotate, without breaking vacuum inside the chamber. The first setup was tested using eight surface barrier silicon detectors, mounted in different telescope configurations, and connected to two MSI-8 electronic systems. Electronic noise was carefully treated, increasing the signal to noise ratio (SNR), and improving the quality of new data. A 2015 experimental campaign was carried out for the following reactions: p(^{6}He,p) ^{6}He; p(^{6}He,α)t; p(^{8}Li,p)^{8}Li; p(^{8}Li,α)^{5}He; p(^{8}Li,d)^{7}Li; ^{120}Sn(^{6}He,^{4}He)^{120}Sn+2n. Spectra confirm the quality of new data. The RIBRAS instrumental update includes new silicon strip detectors (SSD) setup. Detectors from Micronsemiconductors Ltd., will be connected to analogical electronics from Mesytec GmbH & Co (MPR pre-amplifiers and STM-16 amplifiers), logical and digital electronics (Folding Logical Units –FLU and Amplitude to Digital Converters – ADC), from CAEN SpA, and the Motorola VME-5500 processor will connect electronics to the new acquisition system. The use of segmented solid state detectors must enhance the efficiency of angular distribution measurements. In addition, an extension of the RIBRAS beam line was recently installed after the new chamber, to be connected with a gamma-particle cave, shielded by a wall of boron-loaded water, in order to use gamma detectors in a low neutron background environment. The detection of particle

gamma coincidence measurements would enhance the reaction selectivity of the system. Finally, a position-sensitive large area neutron detector, capable to distinguish neutron from gamma rays, is also available to be tested. It must be of value to measure neutron rich nuclei break up, detecting neutrons in coincidence with charged particles.

Marcos A. G. Alvarez, (IF-USP)
on the behalf of RIBRAS collaboration.

Study of the elastic breakup of weakly bound Lithium isotopes at near barrier energies

We have performed CDCC calculations for collisions of ^{6,7}Li projectiles on ^{59}Co, ^{144}Sm and ^{208}Pb targets at near-barrier energies, to assess the relative importance of the Coulomb and the nuclear couplings in the breakup of the two lithium isotopes, as well as the Coulomb-nuclear interference. We have also investigated scaling laws, expressing the dependence of the cross sections on the charge and the mass of the target. We explore the similarities and differences between the results for the two Lithium isotopes, both described as two-cluster nuclei, alpha plus deuteron or tritium. The relevance of the Coulomb dipole and quadrupole strengths at low energy for the two-cluster projectile is investigated in details.

Paulo R. S. Gomes

Microscopic description of elastic scattering with light exotic nuclei

The traditional CDCC method is extended to a microscopic variant, where the projectile is described by a many-body structure. This means that only neutron- and proton-target potentials are needed. The formalism has been first applied to the simple two-cluster 7Li projectile, and is now extended to three-cluster nuclei, such as 6He and 8B. The model provides an opportunity to investigate halo and breakup effects. Recent results, as well as future developments are presented.

Pierre Descouvemont

Chiral EFT forces, shell evolution, shape coexistence and fission: are they in the same cup of tea ?

The shell evolution is one of the characteristic features of exotic nuclei, occurring as one moves on the Segre chart. Recently we pointed out [1] that the same mechanism, particularly its tensor-force contribution, has a significant effect on the shape coexistence. In parallel, we can now see that the QCD-based chiral EFT forces produce exactly the same shell evolution trends as what we have discussed so far.These new developments can be related to another open problem of nuclear physics: why and how fission occurs particularly at its initial stage (including spontaneous ones) ?

Takaharu Otsuka (U. Tokyo)

[1] T Otsuka and Y Tsunoda, J. Phys. G: Nucl. Part. Phys. 43 (2016) 024009

Universal aspects of weakly bound two-neutron halo nuclei

The universal properties of the two-neutron halo nuclei at the drip line will be reviewed. The focus will be on Borromean states with halo neutron orbits dominated by the s-wave, which is the case of Lithium-1Beryllium-14 and Carbon-22. We will also discuss the non-Borromean state of Carbon-20. The halo states are described as a weakly bound three-body system,dominated by the so-called Thomas-Efimov effect. In this case the halo properties are found in a model independent way with only few physical parameters, like scattering lengths and two-neutron separation energy. The presentation will discuss sizes, momentum distributions of the above mentioned nuclei, the universal properties of continuum states at low energies and the comparison with existing experimental data.

Tobias Frederico (ITA-SJC)

Studies of exotic nuclei and explosive stellar burning with fast RI beams at RIKEN RIBF

RIKEN RI Beam Factory (RIBF) is a new-generation facility for radioactive isotope (RI) beams based on the projectile-fragmentation and uranium in-flight fission as production using 345 MeV/nucleon heavy-ion primary beams. RIBF started its regular operation in 2007, and has provided beams of various nuclei very far from the stability valley with world highest intensities. Recent highlights of studies of nuclear structure and astrophysics will be presented. Hot topics include properties of light unbound nuclei, evolution of nuclear shell structure, and nuclear inputs to studies of r-process nucleosynthesis.

Tohru Motobayashi

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The dipole response of exotic nuclei and the nuclear symmetry energy

Large efforts have been undertaken in the past years in order to develop the experimental tools for an investigation of giant resonances in unstable nuclei. Data are still scarce, but promising results have emerged, in particular concerning the dipole response of short-lived nuclei. The interest in studying the multipole response of exotic nuclei is on one hand the nuclear structure aspect concerned with the collective response of neutron-proton asymmetric nuclei, where a change is expected towards a softer response, including possibly new modes of excitation related to the excess nucleons and weak binding. On the other hand, the giant resonances, or the multipole response of heavy nuclei in general, can be related to nuclear matter properties. Measurements for neutron-proton asymmetric nuclei will be able to constrain parameters of the equation of state for asymmetric nuclear matter, as the giant monopole resonance energy for the incompressibility, and the dipole polarizability for the density dependence of the symmetry energy. I will discuss some recent experimental results and developments from the R3B experiment.

Thomas Aumann (TU Darmstadt)

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Phenomenological critical interaction distance from exotic nuclei elastic scattering measurements.

Abstract: Elastic scattering, as a surface process, is very suitable to investigate the peculiar surface properties of the weakly bound exotic nuclei. Analysis of elastic scattering angular distributions can provide valuable information on the static and dynamics effects of exotic nuclei. Although some progress has been achieved inmicroscopic reaction theory, the phenomenological approach, where the projectile interacts with the nucleus as a whole and the interaction between the colliding nuclei is represented by an appropriate potentials, is still a very reliable and practical procedure to analyze these angular distributions. Distances and radius play important role in this phenomenological analyses. To contribute to this we have performed a survey of elastic scattering measurements involving tighly, weakly bound and exotic projectile on heavy and medium mass targets, at energies close to the Coulomb barrier, and analyzed them in terms of the interaction distance. Our goal is to provide a phenomenological investigation of the influence of static and dynamic effects of the exotic properties of some of light nuclei, as 6He, 8B and 11Li, in the elastic scattering measurements.

Valdir Guimaraes (IF-USP)

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Search for Cluster states in light Nuclei with an Active Target TPC: A candidate for a linear quasi-molecular structure in ^{14}C.

I will present our recent finding of candidate linear-chain alpha-cluster states in the neutron-rich nucleus ^{14}C. One-dimensional alignment of alpha_ clusters in atomic nuclei, today known as a `linear-chain' structure, was first proposed in the 1950s. Experimental verification for such an exotic geometry, however, has been a longstanding challenge in nuclear physics. Using resonant _ scattering with a radioactive ^{10}Be beam, we have measured level energies and decay properties of excited states in ^{14}C that our analysis suggests are part of a rotational band with a linear-chain alpha cluster structure predicted by an anti-symmetrized molecular dynamics model. Our result supports not only the existence of linear-chain structure, but also the model's claim that the orthogonality of linear-chain states to other state configurations is essential to the formation of one-dimensional alpha_ clusters in atomic nuclei. Thus, our result opens the door to new experimental linear-chain alpha-cluster studies in nuclear physics as our technique allows us to measure both elastic and inelastic resonances over large angular and energy domains, which is very difficult with conventional methods. While one-dimensional alignment can be found in various many-body systems, our result is one of the rare candidates measured at the femto-meter scale, making our finding of great interest to both nuclear physics and the greater physics community. If results will be already available, some aspects of a very recent experiment at Triumf-Isac with a ^{8}He beam on ^{4}He will be shown in this context.

W. Mittig (MSU-Lansing)