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POSTER SESSION

Monday 22/05/2015
h. 18.00-20.00

Main Hall Dipartimento di Fisica ed Astronomia

POSTER SESSION:

Projected spectroscopic factor for a pair of like-nucleons transfer reaction within the framework of the Richardson model

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Spectroscopic factors have been introduced fifty years ago in the theory of nuclear transfer reactions, in order to link nuclear reactions and structure [1]. The spectroscopic factor is a tool which allows the comparison either between theory and experiments or between theoretical models. On the other hand, pairing correlations play an important role in nuclear structure. The spectroscopic factor may be evaluated either by neglecting these correlations (see e.g. [1]), or by taking them into account (see e.g. [2]). In the latter case, the inclusion of the pairing correlations is often made using the BCS approach. However, the main shortcoming of this approach is the non conservation of the particle-number (see e.g. [3]). A particle-number projection is thus necessary.

In the present work, an expression of the spectroscopic factor for a pair of like-nucleons transfer reaction is established by means of the sharp-BCS (SBCS) projection method [4-5]. It includes pairing correlations between like-particles but the particle-number fluctuations which are inherent to the BCS theory are eliminated. This expression appears as a limit of a sequence which converges as a function of the extraction degree of the false components.

A numerical study is then performed within the framework of the Richardson schematic model [6]. It is shown that the convergence as a function of the extraction degree of the false components is rapid. Moreover, it is shown that the projection effect on the spectroscopic factors is non-negligible. Indeed, the relative discrepancy between the BCS and SBCS values may reach up to 6%. The particle-number fluctuations which are inherent to the BCS approach must then be taken into account in the calculation of the spectroscopic factor of such reactions.

[1] N.K. Timofeyuk, Phys. Rev. **C81,** 064306 (2010).
[2] D.J. Rowe and J.L. Wood, *Fundamentals of Nuclear Models* (World Scientific, Singapore, 2010).
[3] P. Ring and P. Schuck, *The Nuclear Many Body Problem* (Springer, Berlin, 1980).
[4] M.Fellah, T.F. Hammann and D.E. Medjadi, Phys. Rev. **C8,** 1585 (1973).
[5] N.H. Allal, M.Fellah, N. Benhamouda and M.R. Oudih, Phys. Rev. **C77,** 054310 (2008).
[6] R.W. Richardson and N. Sherman, Nucl. Phys. **52,** 221 (1964).

Intermediate energy heavy-ion collisions in asymmetric colliding nuclei: multifragmentation as an example

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We study the fragmentation pattern of various asymmetric reactions at intermediate energies and confront our calculated results with the available experimental data. Our investigations using isospin-dependent quantum molecular dynamics (IQMD) model lead to the conclusion that IQMD model calculations using soft equation of state reproduces the available experimental data nicely around Fermi energies for asymmetric reactions (where most of the incident energy is in the form of thermal energy rather than compressional energy). In spite of the good agreement between calculated and experimental results around Fermi energies, deviation can be seen at extreme lower energies and at higher incident energies. The present study also refutes the anxiety raised earlier that molecular dynamics model may not properly treat the thermodynamical properties [1]. Apart from this, a comparison with various other models (wherever available) is also presented.

[1] R. Donangelo and S. R. Souza, Phys. Rev. C **52**, 326 (1995).

System size dependence of the energy of peak production of fragments

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The break up of the hot and dense nuclear matter into intermediate mass fragments (IMFs), light charged particles (LCPs), medium mass fragments (MMFs) and free nucleons is known as multifragmentation. It is an intermediate mechanism between low energy decay channels like fission, evaporation to high energy decay mode like complete vaporization of the system. Previous studies [1-3] revealed a rise and fall behavior for the multiplicity of IMFs with respect to incident energy of the colliding nuclei. On the other hand, energy dependence of multiplicities of other fragments is still missing. Therefore, we studied the energy dependence of multiplicity of LCPs, MMFs and IMFs for symmetric reactions covering the entire mass range from ^{40}Ca + ^{40}Ca to ^{197}Au + ^{197}Au at semi-central colliding geometry. Our study shows that multiplicity of all fragments first increases with energy, attains a maxima and then decreases. We also find that the extracted values of $E_{c.m.}^{max}$ (energy at which maximum number of fragments are produced) and $\langle N\rangle^{max}$ (maximum multiplicity of fragments) for various mass fragments increase with increase in system mass and show power law behavior with system mass. Further, we observed that higher $E_{c.m.}^{max}$ is observed for light charged particles compared to other mass fragments which are produced at lower incident energies.

References:
[1] D. Sisan *et al*., Phys. Rev. C **63**, 027602 (2001); G. F. Peaslee *et al*., Phys. Rev. C **49**, R2271 (1994).
[2] Y. K. Vermani and R. K. Puri, J. Phys. G: Nucl. Part. Phys. **36**, 105103 (2009).
[3] S. Kaur and A. D. Sood, Phys. Rev. C **82**, 054611 (2010); S. Kaur and R. K. Puri, Phys. Rev. C **87**,
014620 (2013).

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Neutron transfer to the unbound states of ^{11}Be and ^{13}C

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The nucleon transfer reactions as well as the inelastic scattering data are valuable source of information about the halo properties of nuclei not only in the ground states, but in the excited states that is confirmed by recent studies of the halos in the excited nuclear states [1-3] . Our analysis [3] in the framework of the asymptotic normalization coefficients method of the differential cross sections of the ^{12}C(d,p)^{13}C and ^{10}Be(d,p)^{11}Be reactions populated the ground and the first excited bound states allowed us to reveal the halo properties of the first excited states of ^{13}C and ^{11}Be. Now we extend this analysis to the unbound excited states lying above the neutron-emission thresholds of these nuclei.

We present the results of the analysis of ^{12}C(d,p)^{13}C ($5/2^+$, E_x = 3.854 MeV) reaction at incident deuteron energy of 11.8 and 30 MeV, and ^{10}Be(d,p)^{11}Be ($5/2^+$, E_x = 1.785 MeV) reaction at incident deuteron energies of 25.0 MeV. Calculations are carried out within the coupled-reaction channels method for the direct neutron transfer with the FRESCO code [4] and are compared with the experimental data. The unbound states are treated as resonances with the given neutron width and the outgoing-wave asymptotic behavior using the real-valued bins in the continuum. Comparison is made with calculations where these states are presented as quasi-bound states with fictive negative energy ε = 0.01 MeV (Fig. 1). Calculations allowed us to deduce spectroscopic factors and the rms radii of nuclei in these excited states.

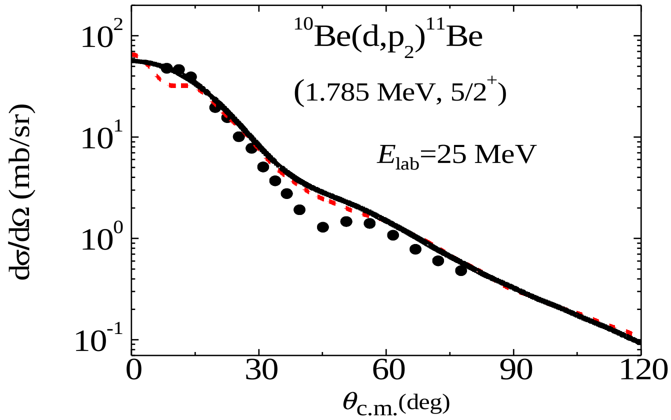

Fig.1 Comparison of the differential cross sections of the ^{10}Be(d,p)^{11}Be reaction populated 1.785-MeV $5/2^+$ state calculated with the resonant (dashed line) and quasi-bound (solid line) n + ^{10}Be wave functions.

[1] A. A. Ogloblin *et al.* Phys. Rev. C **84**, 054601 (2011).
[2] A. A. Ogloblin *et al.* AIP Conf. Proceed. **1224,** 100 (2010).
[3] T. L. Belyaeva *et al.* Phys. Rev. C **90**, 064610 (2014).
[4] I. J. Thompson, Comput. Phys. Rep. **7**, 167 (1988).

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Highlights of the ISOLDE Facility and the HIE-ISOLDE Project

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The ISOLDE Facility at CERN produces radioactive beams through fission, spallation and fragmentation reactions induced by 1.4 GeV protons from the PS booster. The ISOL method involves in this case the bombardment of a thick target with an intense $3x10^3$ proton beam, producing high yields of exotic nuclei with half-lives down to the millisecond range. By a clever combination of target and ion source units including the use of ionization lasers pure beams of 700 different nuclei of 75 elements have been produced and delivered to experiments where properties of the nuclei such as masses, radii, structure and shapes are determined. The high quality of the beams allows high-precision measurements of beta decay and particle correlations including measurement of beta-neutrino correlations in order to prove fundamental interactions in nuclei. Since ten years it offers the largest variety of post-accelerated radioactive beams in the world today. The combination of the Miniball gamma-ray array and T-REX charged particle detection system has been successfully used to study nuclear shapes through Coulomb excitation and transfer reactions up in different region of the nuclear chart. Elastic scattering and transfer in light system has allowed for the study of the interplay between halo structure and reaction mechanism as well to reveal the composition of the few excite states of halo and unbound nuclei.

In order to broaden the scientific opportunities beyond the reach of the present facility, the HIE-ISOLDE (High Intensity & Energy) project will provide major improvements in energy range, beam intensity and beam quality. A major element of the project will be an increase of the final energy of the post-accelerated beams to 10A MeV throughout the periodic table. The first stage will boost the energy of the current REX LINAC to 5 MeV/u where the Coulomb excitation cross sections are strongly increased with respect to the current 3 MeV/u and many transfer reaction channels will be opened.

The first phase of HIE-ISOLDE will start for physics in the autumn of 2015 with an upgrade of energy for all post-accelerated ISOLDE beams up to 5.5 MeV/u. After a submission of thirty-four letters of intend in 2009, twenty-five experiments have been approved for day-one physics with five hundred and eighty shifts. The physics cases approved expand over the wide range of post-accelerated beams available at ISOLDE. A large variety of instrumentation will be implemented. In this presentation HIE-ISOLDE project will be described together with a panorama of the physics cases addressed.

Octupole bands in the neutron-rich nucleus 143Ba

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The reflection asymmetric shell model (RASM) was developed to describe the high spin states in octupole deformed nuclei in Ra-Th octupole deformed nuclei [1] and neutron-rich nucleus 145Ba in Ba-Sm region[2]. In this work, RASM was performed to investigate the reflection asymmetry in 143Ba. All the observed four rotational bands are well reproduced by the present calculation with a proper octupole deformation (∼0.08), which is consistent with the macroscopic-microscopic calculations in the literature. The two octupole deformed neutron Nilsson single-particle orbitals just below the octupole shell gap 88, with K=1/2 and K=3/2 dominate the intrinsic structure of the observed low-lying states. Based on the analysis of the calculated RASM wave functions and the pure-configuration calculation results, the assignments for the observed bands have been given. The s=+i and s=-i octupole bands are all based on the K=1/2 orbit, and they are really “parity doublets” in octupole deformed island around Z=56 and N=88. The calculated results show that the s=+i and s=-i octupole bands in 143Ba are different from the 145Ba. In 145Ba, the s=+i and s=-i octupole bands originate from the different K orbits.

[1] Y. S. Chen and Z. C. Gao, Phys. Rev. C 63, 014314 (2000).

[2] Yong-Jing Chen, Zao-Chun Gao, Yong-Shou Chen, and Ya Tu, Phys. Rev. C 91, 014317 (2015).

Large electron screening effect in $^{1}H(^{7}Li,\alpha)^{4}He$ and $^{1}H(^{19}F,\alpha\gamma)^{16}O$ reactions in different environments

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In reactions between nuclei at very low energies, when the energy of the incident beam in the center of mass system is far below the Coulomb barrier, the only way the reaction can happen is by tunneling. In this case, since the projectile has to penetrate through the huge potential barrier, the reaction rate is very low and sensitive to electronic properties of target materials. The electrons surrounding the reacting nuclei can increase the tunneling probability through the Coulomb barrier leading to an enhancement of nuclear reaction rates. Thermonuclear reactions are important in understanding the nucleosynthesis of elements in the universe and the energy generation in stars. But considering the fact that atoms in the stellar interior are in most cases in highly stripped states and nuclei are immersed in a sea of free electrons which tend to cluster closer to the nucleus than in atoms, we do not expect that the electron screening effect observed in the laboratory should be equal to electron screening in the stars. To be able to explain the electron screening in the stars, it is important that we first understand the electron screening effect under laboratory conditions.

But unfortunately, our understanding of electron screening is still poor. Even nowadays the very nature of this effect is unclear. The latest studies suggest that it is not a static, but rather a dynamic process [1]. What is known from previous experiments is that the amplitude of electron screening potential is much higher when the reaction takes place inside a metal than in an insulator or semiconductor [1-5]. Significant differences of the amplitude of the screening potential were observed between various host metals and the origin of this is not yet understood. Also, the experimental results indicate a dependence of the electron screening potential on the proton number Z of the projectile, but the form of this dependence is not known.

With the motivation to contribute to these investigations of the electron screening effect and to provide a deeper understanding of this topic, we studied the $^{1}H(^{7}Li,\alpha)^{4}He$ and $^{1}H(^{19}F,\alpha\gamma)^{16}O$ reactions in inverse kinematics on hydrogen implanted C, Pd, and W targets. Contrary to expectations, large electron screening potential was found in all three targets. From our results we also tried to deduce the dependence of the electron screening potential on the proton number Z of the projectile. Preliminary results show that this dependence is not linear.

[1] J. Gajević *et al.*, Eur. Phys. J. A **49**, 70 (2013).

[2] F. Raiola *et al.*, Eur. Phys. J. A **19**, 283 (2004).

[3] J. Cruz *et al.*, Phys. Lett. B **624**, 181 (2005).

[4] K. U. Kettner *et al.*, J. Phys. G **32**, 489 (2006).

[5] M. Lipoglavšek *et al.*, Eur. Phys. J. A **44**, 71(2010).

Cluster rotational bands in ^{11}B

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Differential cross-sections of the ^{11}B + α inelastic scattering at $E(\alpha)$ = 65 MeV leading to the most of the known ^{11}B states at the excitation energies up to 14 MeV were measured [1]. The data analysis was done by DWBA and in some cases by the Modified Diffraction Model [2] allowing determining the radii of the excited states. The radii of the states with excitation energies less than ~ 7 MeV with the accuracy not less than 0.1-0.15 fm coincide with the radius of the ground state. This result is consistent with the traditional view of the shell structure of the low-lying states in ^{11}B. Most of the observed high-energy excited states are distributed among four rotational bands:

K = $3/2^-$: 8.56 ($3/2^-$) – 10.34 ($5/2^-$) – 11.60 – 13.14 ($9/2^-$) MeV,
K = $1/2^+$: 6.79 ($1/2^+$) – 9.88 ($3/2^+$) – 11.60 ($5/2^+$) – 13.16 ($7/2^+$) MeV,
K = $3/2^+$: 7.98 ($3/2^+$) – 9.27 ($5/2^+$) – 10.60 ($7/2^+$) – 12.63 ($9/2^+$) MeV,
K = $5/2^+$: 7.29 ($5/2^+$) – 9.19 ($7/2^+$) – 11.27 ($9/2^+$) MeV.

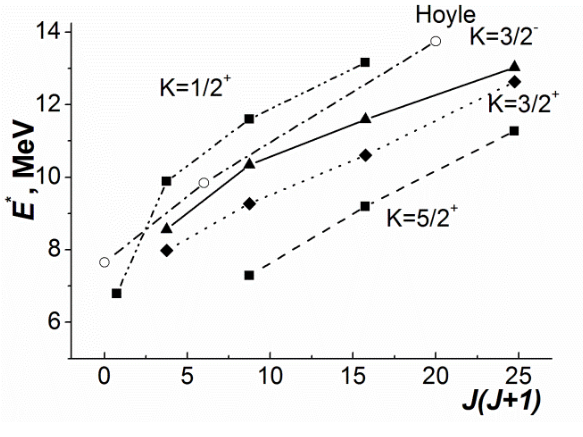

Fig. 1. Predicted [3,4] rotational bands in ^{11}B at excitation energies higher 7 MeV. For comparison, rotational band [5], based on the Hoyle state (0^+_2. 7.65 MeV) of ^{12}C, is shown.

The moments of inertia of band states are close to the moment of inertia of the Hoyle state of ^{12}C. The determined radii, related to these bands, are 0.7 - 1.0 fm larger than the radius of the ground state, and are close to the radius of the Hoyle state. These results are in agreement with existing predictions about various cluster structure of ^{11}B at high excitation energies.

[1] A.N. Danilov, A.S. Demyanova *et al.*, Physics of Atomic Nuclei, in print
[2] A.N. Danilov *et al.*, Phys.Rev. C **80,** 054603 (2009)
[3] T. Suhara and Y. Kanada-En'yo, Phys. Rev. C **85**, 054320 (2012)
[4] H. Yamaguchi *et al.*, Phys. Rev. C **83,** 034306 (2011)
[5] A.A. Ogloblin *et al.*, EPJ Web of Conferences, **66,** 02074 (2014)

States of ^{13}C with abnormal radii

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In our previous experiment on the inelastic scattering ^{13}C (α,α') at E(α) = 65 MeV [1] we claimed the observation of three excited states whose radii differed from that of the ground state: 3.09 MeV ($1/2^+$), 8.86 MeV ($1/2^-$) and 9.90 MeV ($3/2^-$). In this paper we continued the analysis including in it some other data. The evaluation of radius of the 3.09 MeV state was performed by three independent methods, Modified diffraction model (MDM) [2], Nuclear rainbow method (NRM) [3, 4] and method using the asymptotic normalization coefficients (ANC) [5, 6]. The radius occurred to be enhanced in good agreement with theoretical predictions [7] demonstrating the existence of a neutron halo in this state. All three approaches gave similar values verifying the validity of the used methods. Application of MDM and NRM to the 8.86 MeV state showed that the latter also has an enhanced radius close to that of the Hoyle state (7.65 MeV, 0^+) of ^{12}C [2]. The radius value of the 9.90 MeV remains an open question. The estimates done both by MDM and NRM methods gave the value less than that of the ground state. As this state is considered to be the head of the $3/2^-$ rotational band [8], and its enhanced radius is predicted [9] a more elaborate analysis of the problem is required. Because of the importance of the obtained result new measurements of the inelastic scattering ^{13}C (α,α') at E(α) = 90 MeV were performed. The analysis is in progress.

[1] A.S. Demyanova et al., EPJ Web of Conferences **66**, 02027 (2014)
[2] A.N. Danilov et al., Phys. Rev. C **80**, 054603 (2009)
[3] S.Ohkubo and Y. Hirabayashi, Phys. Rev. C **75,** 044609 (2007)
[4] A.S. Demyanova et al., Int. J. Mod. Phys. E **20**, No 4, 915 (2011)
[5] Z.H. Liu et al., Phys. Rev. C **64**, 034312 (2001)
[6] T.L. Belyaeva et al., Phys.Rev. C **90**, 064610-1 (2014)
[7] T. Yamada and Y. Funaki, Int. J. Mod. Phys. E **17**, 2101 (2008)
[8] M. Milin and W. von Oertzen, Eur. Phys. J. A **14,** 295 (2002)
[9] N. Furutachi, M. Kimura, Phys. Rev. C **83**, 021303® (2011)

The observation of Element 117: Opportunity for next generation experiments with the new ALBEGA multi-coincidence detection setup

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The present knowledge of the nuclear structure of superheavy nuclei (SHN) is still scarce, in spite of large experimental and theoretical efforts devoted to this problem in the last decades. This is mainly due to the low production rate of these nuclei. The synthesis of SHN can be achieved preferably by heavy-ion induced fusion-evaporation reactions and can easily require a day, a week, or several months of beam time for single event observation [1].

Such measurements are typically performed with in-flight recoil separators in combination with a detection setup. I will present the results of a recent experiment on the production of the element with Z=117 [2] as an example of a SHN program conducted at the upgraded gas-filled recoil separator TASCA (the TransActinide Separator and Chemistry Apparatus). Experiments on ^{294}117 performed at TASCA [2] and DGFRS (the Dubna Gas-Filled Recoil Separator) [3] both report that many decay products along the decay chain feature half-lives longer than 1 s. This offers, as a complementary approach, opportunities to chemically isolate these isotopes, as was done, e.g. in [4].

It has been experimentally shown that physics experiments can benefit from a chemical isolation [5]. In particular, the application of chemical isolation to the ions selected with a recoil separator has significantly improved the background conditions, as described in Refs. [4-7]. So far, e.g., the gas-thermochromatography detector setups like COMPACT [5] or COLD [7] were successfully used. A next generation setup, ALBEGA (for measurements of ALpha-BEta-GAmma decays after chemical isolation) was recently developed at GSI. ALBEGA is dedicated to collect spectroscopic data by detecting simultaneously α-particles, electrons, photons, and fission fragments. I will present the current status of ALBEGA and an outlook on its future applications.

References

[1] J. H. Hamilton, S. Hofmann and Yu. Ts. Oganessian, Ann. Rev. Nucl. Part. Sci. 63, 383 (2013).

[2] J. Khuyagbaatar et al., Phys. Rev. Lett. 112, 172501 (2014).

[3] Yu. Ts. Oganessian, Phys. Rev. Lett. 104, 142502 (2010).

[4] A. Yakushev et al., Inorg. Chem. 53, 1624-1629 (2014).

[5] J. Dvorak et al., Phys. Rev. Lett. 97, 242501 (2006).

[6] J. Even et al., J. Radioanal. Nucl., in press (2015) doi: 10.1007/s10967-014-3793-7.

[7] D. Wittwer et al., Nucl. Inst. and Meth. B 286, 28-35 (2010).

Symmetry energy of finite nuclei and nuclear matter

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The symmetry energy relates the heavy ion reactions, stability of superheavy nuclei, fusion cross sections and structures, composition and cooling of neutron stars. Many theoretical and experimental efforts have been performed to its density dependence. However, this problem remains unsolved. Based on the Skyrme energy density functional, we derived directly the density functional for the symmetry energy, and obtain the spatial distribution of the symmetry energy of a finite nucleus [1]. It is found that the surface part of a heavy nucleus contributes dominantly to its symmetry energy compared to its inner part. The symmetry energy coefficient is then directly extracted and the ratio of the surface symmetry coefficient to the volume symmetry coefficient κ is estimated, which agrees with that obtained from the measured nuclear masses. In addition, with the help of experimental β^--decay energies of heavy odd-A nuclei and experimental nuclear mass differences, the symmetry energy coefficient of heavy nuclei is determined [2,3]. This result is used to analyze the density dependence of the symmetry energy of nuclear matter around the saturation density, and furthermore, the neutron skin thickness of ^{208}Pb can be deduced.

[1] Jianmin Dong, Wei Zuo, and Jianzhong Gu, Phys. Rev. C **87**, 014303 (2013).
[2] Jianmin Dong, Haifei Zhang, Longjun Wang, Wei Zuo, Phys. Rev. C **88**, 014302 (2013).
[3] Xiaohua Fan, Jianmin Dong, and Wei Zuo, Phys. Rev. C **89**, 017305 (2014).

Study of fusion-fission dynamics in ^{19}F+^{238}U reaction

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Over the years, a large number of experiments have been performed to study the dynamics of fusion-fission mechanism in heavy ion induced reactions. These studies are important for better understanding of the reaction dynamics involved in the formation of super heavy elements in laboratory. Apart from pure fusion-fission, the existence of pre-equilibrium fission (PEQ) and quasi-fission (QF) add further complexity to the reaction dynamics. They are found to be the competing reaction channels for light ion induced reactions with actinide targets. Though many studies have been performed in this mass region, there are still inconsistency in the results of many of these reactions. For example, the angular anisotropies of fission fragments measured in reactions ^{19}F, ^{16}O, ^{12}C + ^{232}Th, ^{238}U [1,2,3] have been found inconsistent with the statistical saddle point model (SSPM) predictions. It has been reported that PEQ fission mechanism, i.e., departure from K equilibration before fission events might be responsible for these anisotropies. However for reactions of ^{19}F, ^{16}O, ^{12}C on ^{232}Th [4], the mass distribution of fragments showed evidence of QF, i.e., no mass equilibration before fission. In the recent work, presence of QF is evident in the reaction ^{18}O+^{232}Th as compared to the ^{12}C+^{238}U system[5]. In the present work, we performed the mass distribution of fission fragments in the reaction ^{19}F+^{238}U where large anisotropy has been reported in angular distribution.

Experiment was performed in the general purpose scattering chamber(GPSC) facility at Inter University Accelerator Centre (IUAC), New Delhi using 15UD tandem accelerator. Pulsed beam of ^{19}F with a repetition rate of 250 ns was bombarded on ^{238}U targets with laboratory energy range of 80 to 120 MeV. Two large area multi-wire proportional counters (MWPCs) were used to detect fission fragments.

Mass variance of fission fragments for ^{19}F+^{238}U reaction has been measured around the sub-barrier energies. Mass variance are found to be consistent with those found in systems ^{12}C+^{238}U and ^{16}O+^{238}U around sub-barrier energies. Similar trends of mass variance for reactions ^{19}F, ^{16}O, ^{12}C + ^{232}Th has been observed. Additionally, mass angle correlation measurements for ^{19}F+^{238}U exhibits similar kind of behavior as ^{12}C+^{238}U and ^{16}O+^{238}U systems. Hence it can be concluded that, ^{19}F, ^{16}O, ^{12}C + ^{232}Th, ^{238}U reactions exhibit departure from mass equilibration before fission process, i.e., QF mechanism will be significant part of the fission mechanism in these reactions.

[1] J.C. Mein *et al.*,Phys. Rev. C , 55, R995 (1997).
[2] J. P. Lestone *et al.*, Phys. Rev. C , 56, R2907(1997).
[3] V. S. Ramamurthy *et al.*, Phys. Rev. Lett. ,65, 25(1990).
[4]T.K. Ghosh *et al.*, Physics Letters B , 627 (2005).
[5]C.Yadav *et al.*, Phys. Rev. C , 86, 034606 (2012).

Particle-number projection effect, in the isovector pairing case, on the energy of odd mass N≈Z nuclei

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The neutron-proton pairing correlations effect has a key role in the structure of exotic nuclei such as N≈Z [1]. In the present work, we will focus on the isovector pairing case. These correlations are usually treated by means of the BCS approach [2]. However, the usual generalized BCS wave-function can only describe even-even systems or some odd-odd ones. Dealing with odd systems, an expression of the ground-state has been recently proposed using the blocked-level technique [3]. It is more satisfying that the previously used one [4-5]. However, this wave-function does not conserve the particle-number. In the present work, it is projected by means of the sharp-BCS (SBCS) projection method [6]. Expressions of the energy of the system, as well as the variance on the particle-number, are derived. The formalism is applied to odd mass N≈Z nuclei. It is shown, on the one hand that the particle-number fluctuations are eliminated, and on the other hand that the projection effect on the energy is non-negligible.

[1] A. A. Raduta, M. I. Krivoruchenko and A.Faessler, Phys. Rev. **C85,** 054314 (2012).
[2] F. Simkovic, Ch. C. Moustakidis, L. Pacearescu and A. Faessler, Phys. Rev. **C68,** 054319 (2003).
[3] M. Fellah, N.H. Allal and M.R. Oudih, Fourth International Congress on Advances in Applied Physics and Materials Sciences 2014 (APMAS 2014), Oludeniz, Turkey, April 2104
[4] F. Hammache, N.H. Allal and M. Fellah, Int. J. Mod. Phys. **E21,** 1250100 (2012).
[5] A. Berbiche, M. Fellah and N.H. Allal, J. Theor. Appl. Phys. **8,** 118 (2014).
[6] N.H. Allal, M. Fellah, M.R.Oudih and N. Benhamouda, Eur. Phys. J A **27,** s01, 301 (2006).

Thermal binding energies in clusterization algorithm and its effect on fragmentation

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Multifragmentation has gained considerable attention and has been studied very intensely since last three decades [1]. From the vast available literature on fragmentation, it is observed that fragments are not cold at the time of detection [2]. On the other hand, most of the studies on fragmentation by dynamical models took fragments to be bound if they fulfill the cold matter properties [3]. At the same time some employed secondary algorithms to de-excite the fragments. Therefore, in the present study, our aim is to see how fragmentation pattern is affected if fragments are considered to be at few MeVs of temperature. This has been done by subjecting the fragments to fulfill the temperature-dependent binding energies constraint [4]. For this we simulated the semi-central collisions of ^{197}Au+^{197}Au at 400 MeV/nucleon using Quantum Molecular Dynamics model (QMD) [5]. Our findings [6] reveal that the multiplicity pattern for fragments is significantly affected if the fragments at the freeze out time are taken to be at finite temperature.

References:

[1] C. Sfienti *et al.,* Phys. Rev. Lett. **102**, 152701 (2009); D. R. Bowman *et al., ibid.* **67**, 1527 (1991).
[2] J. Wang *et al.,* Phys. Rev. C **72**, 024603 (2005); R. Wada *et al., ibid*. C **55**, 227 (1997).
[3] S. Goyal and R. K. Puri, Phys. Rev. C **83**, 047601 (2011); Y. K. Vermani, R. K. Puri, Cent. Eur. J. Phys. **9**, 621-627 (2011).
[4] N. J. Davidson *et al.,* Nucl. Phys. A **570**, 61c (1994); C. Guet *et al*., Phys. Lett. B **205**, 4 (1988).
[5] J. Aichelin, Phys. Rep. **202**, 233 (1991).
[6] R. Kumar, S. Gautam and R. K. Puri, Phys. Rev. C **89**, 064608 (2014).

Dynamics of fragmentation in heavy-ion collisions at intermediate energies

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We study the dynamics of fragmentation using quantum molecular dynamics approach [1] in the energy range of 50 and 400 MeV/nucleon. The energy dependence of multiplicities of various mass fragments (medium mass fragments, intermediate mass fragments and heavy mass fragments) and light charged particles is investigated for various reactions between ^{40}Ca+^{40}Ca and ^{197}Au+^{197}Au and study revealed a rise and fall behavior of fragment's multiplicity for all mass fragments, as observed earlier for intermediate mass fragments only [2]. Also, the use of spatial constraints for clustering nucleons, termed as minimum spanning tree (MST) method, is validated by subjecting these (preliminary) fragments to temperature-dependent binding energy check (MST-BT) over cold matter binding energy (MST-B) constraint. The fragmentation pattern obtained using MST is close to that with MST-BT, rather than MST-B, thus validating the conventional MST method [3].

[1] J. Aichelin, Phys. Rep. **202**, 233 (1991); R. K. Puri and S. Kumar, Phys. Rev. C **57**, 2744 (1998); S. Goyal and R. K. Puri, *ibid*. C **83**, 047601 (2011); C. Hartnack *et al*., Eur. Phys. J A **1**, 151 (1998); S. Gautam, Phys. Rev. C **88**, 057603 (2013).

[2] D. Sisan *et al*., Phys. Rev. C **63**, 027602 (2001); Y. K. Vermani and R. K. Puri, J. Phys. G: Nucl. Part. Phys. **36**, 105103 (2009); S. Kaur and R. K. Puri, *ibid*. C **87**, 014620 (2013).

[3] R. Kumar, S. Gautam and R. K. Puri, Phys. Rev. C **89**, 064608 (2014).

Transfer to the continuum calculations of quasifree (p,pn) and (p,2p) reactions

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Nucleon removal (p,pn) and (p,2p) reactions at intermediate energies have gained renewed attention in recent years as a tool to extract information from exotic nuclei, thanks to the availability of exotic beams with which to perform these reactions in inverse kinematics. The information obtained from these experiments is complementary to that obtained from nucleon removal experiments with heavier targets (knockout), but is expected to be sensitive to deeper portions of the wave function of the removed nucleon.

In this contribution, we present calculations for (p,2p) and (p,pn) reactions performed within the transfer to the continuum method [1]. This is a fully quantum-mechanical formalism, based on the application of the prior form transition amplitude, in which the 3-body final states are expanded in a discretized basis of p-N continuum states. This method is expected to be suitable for the analysis of observables of inclusive nature which are currently under study in the experiments performed at GSI. Results for stable and unstable nuclei are presented, employing Reid Soft-Core nucleon-nucleon interaction [2] and microscopic nucleus-nucleon potentials for the entrance and exit channels calculated by folding the effective Paris-Hamburg g-matrix NN interaction [3] with Hartree-Fock densities.

[1] A.M. Moro, F.M. Nunes, Nucl. Phys. A **767**, 138 (2006)
[2] V.G.J. Stokes *et al.*, Phys. Rev. C **49**, 2950 (1994)
[3] H.V. von Geramb, AIP Conf. Proc. **97**, 44 (1983)

Indirect study of the $^{16}O+^{16}O$ fusion reaction toward stellar energies by the Trojan Horse Method

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The $^{16}O+^{16}O$ fusion reaction is important in terms of the explosive oxygen burning process during late evolution stage of massive stars as well as understanding of the mechanism of low-energy heavy-ion fusion reactions. The astrophysical S-factor of such a heavy-ion fusion strongly depends on energy at corresponding stellar temperatures far below the Coulomb barrier. For the $^{16}O+^{16}O$ reaction cross section, there are large discrepancies among different experiments and also among theoretical predictions, and is a lack of data below $E_{\rm cm} = 7$ MeV. We aim to determine the excitation function for the most major exit channels, $\alpha+^{28}Si$ and $p+^{31}P$, toward stellar energies indirectly by the Trojan Horse Method via the $^{16}O(^{20}Ne, \alpha^{28}Si)\alpha$ and $^{16}O(^{20}Ne, p^{31}P)\alpha$ three-body reactions. We have performed measurements twice using WO_3 targets and ^{20}Ne beams at different beam energies at Heavy Ion Laboratory (45 MeV) and Gumilyov Eurasian National University (35 MeV). We will present preliminary results involving reaction identification, determination of the momentum distribution of α-^{16}O intercluster motion in the projectile ^{20}Ne nucleus, the half-off-energy-shell two-body reaction cross section for the $\alpha+^{28}Si$ and $p+^{31}P$ channels, etc.

Transverse Isotropy: Disappearance of Mott oscillations in sub-barrier elastic scattering of identical heavy ions

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The scattering of identical Bosonic nuclei at low energies exhibits conspicuous Mott oscillations which can be used to investigate the presence of components in the predominantly Coulomb interaction arising from several physical effects. It is found that at a certain critical value of the Sommerfeld parameter the Mott oscillations disappear and the cross section becomes quite flat. We call this effect Transverse Isotropy (TI) (L. F. Canto, R. Donangelo and M. S. Hussein, Mod. Phys. Lett. A, **16**), 1027 (2001).. The critical value of the Sommerfeld parameter at which TI sets in is found to be $\eta_c = \sqrt{3s+2}$, where s is the spin of the nuclei participating in the scattering. No TI is found in the Mott scattering of identical Fermionic nuclei. The critical center of mass energy corresponding to η_c is found to be $E_c = 0.40$ MeV for $\alpha + \alpha$ (s = 0) , and 1.2 MeV for ^{6}Li + ^{6}LI (s = 1). We further found that the inclusion of the nuclear interaction induces a significant modification in the TI (L. F. Canto, M. S. Hussein and W. Mittig, Phys. Rev. C, **89** 024610 (2014)). By calculating the second derivative of the cross section for $\alpha+\alpha$ at $\theta = 90^o$, one can observe that the nuclear interaction drastically changes the picture, resulting in two solutions for η_c and correspondingly E_c, takes on two critical values, one at about the aforementined value of 0.40 MeV and higher one at 1.2 MeV. We suggest measurements at these sub-barrier energies for the purpose of extracting useful information about the nuclear interaction between light heavy ions.

Semiclassical approach to sequential fission in peripheral collisions

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A closed-form semiclassical approach describing in a single picture both the evaporation component and the fast nonequilibrium component of the sequential fission of projectilelike fragments in a peripheral heavy-ion collision is derived and then applied to the dynamical fission observed in the ^{124}Sn+^{64}Ni peripheral collision at 35A MeV. Information on opposite polarization effects of the fissioning projectilelike fragments and on "dynamical fission lifetimes" are obtained. This approach allows, in spite of its simplicity, to reproduce many of the observed features of both E and NE in-plane angular distributions of the heavier fragment from the PL nucleus splitting.

[1] E. De Filippo *et al.*, Phys. Rev. C **71**, (2005) 064604, and references therein.
[2] A. Strazzeri and A. Italiano, Int. J. Mod. Phys. E **23**, (2014) 1450081, and references therein.

Analysis of the reaction size by the method of the scattering radius

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In light nuclear systems, it is well known that cluster structures appear in excited states. One of characteristic properties in cluster structures is a prominent extension of nuclear radius. A typical example is the Hoyle 0_2^+ state in ^{12}C, which has a developed 3α cluster structure, and the radius of the 3α state is expected to be enhanced by about 50 percent in comparison with the radius of the ground state [1]. However, the enhanced radius of the 3α state is not confirmed experimentally.

Recently we have proposed a spatial measure, "scattering radius", which characterizes a size of an exclusive reaction in the basis of the general coupled-channel formalism [2]. In the present study, we apply the method of the scattering radius to the proton + ^{12}C scattering, and the spatial radius for the inelastic scattering to the Hoyle 0_2^+ state is evaluated. First, we perform the microscopic coupled-channel calculation (MCC). In the MCC calculation, the proton – ^{12}C nuclear interactions are derived by the folding procedure. We employ the microscopic ^{12}C transition density [1] and the DDM3Y effective nucleon-nucleon interaction [3]. As for the internal excitations of ^{12}C, the collective (2_1^+ and 3_1^-) and cluster states (0_2^+ and 2_2^+) are included. The differential cross sections are calculated in the energy range from $E_p = 30$ MeV to $E_p = 65$ MeV, and all the parameters are tuned to reproduce the observed cross sections.

Secondly, from the partial cross sections calculated in MCC, we define the effective orbital spin $\bar{L}$, which mainly contributes to the scattering to the individual channels. The scattering radii (R_{SC}) are derived from the simple reation in the classical mechanics, such as $\bar{L} = kR_{SC}$ with the incident proton momentum k. The results are summarized in Table. 1.

Table 1: Effective orbital spin $\bar{L}$ and scattering radius R_{SC} at E_p= 65 MeV. At the right-most column, the root-mean-squared radii (*r.m.s.*) in Ref.[1] are presented for a comparison.

Channel	Energy (MeV)	$\bar{L}$	R_{SC} (fm)	*r.m.s.* (fm)
0_1^+ (elastic)	0.00	4.64	2.73	2.40
0_2^+ (3α)	7.65	6.37	3.74	2.62

As shown in Table.1, a strong enhancement of R_{SC} in the 0_2^+ channel has been found in comparison to that of the elastic (0_1^+) channel. The feature of R_{SC} nicely corresponds to the root-mean-squared radius (*r.m.s.*) obtained in the structure calculation of ^{12}C [1]. Thus, the enhancement of R_{SC} in the 0_2^+ channel is considered to have a close connection to the large radius of the Hoyle 0_2^+ state having the 3α structure. In the present report, we will explain the details of the method of the scattering radius and discuss the enhancement mechanism of the scattering radius in the 3α excitation.

[1] M. Kamimura, Nucl. Phys. A351, 456 (1981).
[2] M. Tomita et al., Phys. Rev. C89,034619 (2014).
[3] A. M. Kobos et al, Nucl. Phys. A425, 205 (1984).

^{9}Be scattering in a four-body CDCC framework

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We describe the scattering of ^{9}Be on ^{208}Pb, ^{120}Sn and ^{27}Al within a four-body Continuum-Discretized Coupled-Channels (CDCC) framework [1,2], considering a three-body projectile plus a structureless target. The three-body $\alpha + \alpha + n$ states are generated using a pseudo-state (PS) method, called the analytical transformed harmonic oscillator (THO) method [3]. PS methods consist in diagonalizing the Hamiltonian of the system in a complete set of square-integrable functions. The THO basis is generated with an analytical local scale transformation of the harmonic oscillator functions, and the parameters of the transformation govern the density of PS at a given energy, allowing the construction of an optimal basis for each observable of interest. Our method can be used in general for systems with several charged particles, and describes both bound and continuum (resonant and non-resonant) states of the system. We applied this method recently to describe the properties of ^{9}Be and the astrophysical $\alpha(\alpha n, \gamma)^9$Be reaction rate [4].

The total four-body projectile-target wave function is expanded in internal states of the three-body projectile [5]. Breakup effects are considered including explicitly the coupling to the continuum part of the spectrum. We solve the coupled-channel system and obtain the elastic angular distributions and breakup cross sections for the different reactions. We show the relevance of the continuum couplings for this weakly-bound projectile, especially at energies below the Coulomb barrier. The effect of projectile resonances on the cross sections is also analyzed. The agreement with the available experimental data [6-9] is rather reasonable and supports the reliability of our three-body model to describe the structure of ^{9}Be.

[1] M. Yahiro *et al.*, Prog. Theor. Phys. Suppl. **89**, 32 (1986)
[2] N. Austern *et al.*, Phys. Rep. **154**, 125 (1987)
[3] J. Casal *et al.*, Phys. Rev. C **88**, 014327 (2013)
[4] J. Casal *et al.*, Phys. Rev. C **90**, 044304 (2014)
[5] M. Rodrguez-Gallardo *et al.*, Phys. Rev. C **77**, 064609 (2008)
[6] R. J. Woolliscroft *et al.*, Phys. Rev. C **69**, 044612 (2004)
[7] N. Yu *et al.*, J. Phys. G **37**, 075108 (2010)
[8] P. R. S. Gomes *et al.*, Phys. Rev. C **70**, 054605 (2004)
[9] A. Arazi *et al.*, private communication (2014)

Examination of positive Q-value multi-neutron transfer channel couplings on fusion barrier distribution for the ^{28}Si+^{154}Sm system

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It is well established that the interplay between nuclear structure and reaction dynamics can lead to enhancement of sub-barrier fusion cross sections, when compared with single-barrier predictions [1]. However, the role of neutron transfer in heavy-ion fusion is still not well understood. Systems like ^{40}Ca + ^{124,132}Sn [2], and ^{28}Si + ^{124}Sn [3] show effects on the enhancement, and on the related barrier distributions, due to the presence of positive Q-value neutron-transfer channels. But fusion in systems such as ^{58,64}Ni + ^{124,132}Sn, despite the presence of positive Q-value channels, do not show such a correlation [4]. Recently, it has been reported that couplings to positive Q-value neutron transfer channels are important if they lead to a change in the deformation of the colliding nuclei [5]. However, most of the systems studied involved spherical nuclei where the couplings take place to surface vibrations. It is, therefore, of interest to look for possible transfer effects in the presence of a static deformation of the target and/or projectile.

Moreover, the fusion barrier distribution (BD) has been shown to permit deeper insight into fusion dynamics than the cross section itself. With the above motivation in mind, a quasi-elastic BD measurement has been carried out for the ^{28}Si+^{154}Sm system, whose target possesses a large static deformation. Precise quasi-elastic cross sections were measured for this system at large backward angles using the HYTAR (HYbrid Telescope ARray for quasi-elastic measurements) facility at IUAC, New Delhi and experimental BD was extracted using the method proposed by Timmers *et al.* [6]. The predictions of coupled channels calculations, including the collective excitation of the target and projectile, are observed to reproduce the experimental BD rather well, indicating that the role of neutron transfer is in fact weak in this system. This observation is consistent with the earlier conclusion that the decrease in deformation parameter of residual nuclei after neutron transfer has no significant effect on fusion excitation function around Coulomb barrier energies [5]. The hexadecapole deformation of the ^{154}Sm nucleus has also been obtained from the BD analysis. Details of the experiment and coupled channel analysis will be presented during the conference.

[1] M. Dasgupta *et al.*, Annu. Rev. Nucl. Part. Sci. **48**, 401 (1998).
[2] J.J. Kolata *et al.*, Phys. Rev. C **85**, 054603 (2012).
[3] L.S. Danu *et al.*, Phys. Rev. C **89**, 044607 (2014).
[4] Z. Kohley *et al.*, Phys. Rev. Lett. **107**, 202701 (2011).
[5] V.V. Sargsyan *et al.*, Phys. Rev. C **91**, 014613 (2015).
[6] H. Timmers *et al.*, Nucl. Phys. A **633**, 421 (1998).

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Role of asymmetry effects in projectile fragmentation using momentum dependent interactions.

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One of the most important challenges in heavy ion physics is the determination of the nuclear equation of state (NEOS) of asymmetric nuclear matter which plays an important role at low energy phenomena like fusion-fission, nuclear structure etc; intermediate energy phenomena like multifragmentation, fragment flow, nuclear stopping etc; and at last high energy phenomena like pion and kaon production. The momentum dependent interactions are found to be the prominent candidate to study the NEOS of asymmetric nuclear matter. It is well known that the dynamics for symmetric and asymmetric reactions is entirely different [1]. When reaction takes place, the formation of participant as well as spectator zone takes place. Participant zone in the presence of momentum dependent interactions (MDI) play very important role. In the participant zone, the projectile nucleons feel strong repulsion due to target nucleons in the presence of MDI. Due to this large density gradient, asymmetric collisions become equally important in the presence of MDI.

In the present study, the multifragment decay (projectile fragmentation) of heavy projectile is explored at relativistic bombarding energy of 600 MeV/nucleon. The simulations of mass asymmetric target and projectile combinations of ^{124}Xe+^{100}Ru (η=0.1), ^{156}Gd+^{68}Zn (η=0.3), ^{173}Yb+^{51}V (η=0.5), ^{197}Au+^{27}Al (η=0.7) for A_{total} = 240 over the entire collision geometry has been carried out using soft momentum dependent equation of state using the isospin dependent quantum molecular dynamics model [2].

Fig.1 shows the variation of multiplicity of intermediate mass fragments (IMFs) with the impact parameter for the reactions involving the heavy projectile and light target combination. It is clear that with increase in mass asymmetry, the production of IMFs increases and is found to be maximum at central collisions. This is due to the reason that the excitation energy deposited in spectator part is maximum in central collisions for large η. Therefore it is clear that the mass asymmetry parameter plays an important role in the projectile fragmentation.

References:

[1] V. Kaur and S. Kumar, J. Phys. G: Nucl. Part. Phys.39, 085114 (2012); V. Kaur and S. Kumar, Phys. Rev. C81, 064610 (2010).
[2] C. Hartnack, R. K. Puri, J. Aichelin, J. Konopka, S. A. Bass, H. Stocker, and W. Greiner, Eur. Phys. J. A 1, 151 (1998).

Statistics of magnetar crusts magnetoemission

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The ultra-magnetized astrophysical objects, i.e., magnetars, were invoked to interpret an activity of soft gamma repeaters (SGRs) and anomalous X-ray pulsars (AXPs). Many various observational data for these pulsars strongly support the magnetar concept implying, thereby, enormous stellar magnetization with field strengths up to ten of *tera-tesla*.

In this contribution the SGR burst emission is considered as a release of magnetic energy stored in the baryonic degrees of freedom of neutron star. Particular attention is paid for magnetodynamics of star outer crusts being plausibly composed of well-separated magic nuclei, cf. [1]. The nuclear magnetization is demonstrated to display the sharp abrupt field dependence due to quantization of spatial motion. As shown for neutron star crusts such jump anomalies of magnetic moments in conjunction with ferromagnetic inter-nuclide coupling give rise to jerky magnetodynamics with erratic sharp step-wise discontinuities in the crust (de)magnetization process due to avalanche propagation. As a consequence, sudden energy release to the magnetosphere leads to SGR-burst, cf. [1].

For the description of such noisy collective magnetoemission of neutron star crusts we develop the Randomly Jumping Interacting Moments (RJIM) model accounting for quantum fluctuations due to the discrete level structure, inter-nuclide coupling, disorder and demagnetization energy. The comparison of model predictions with observational data allows, therefore, to quantify crust properties. As shown the predicted by RJIM model scaling behavior for, e.g., the burst intensity and waiting time distributions are in a good agreement with SGR observations supporting thereby the credibility of RJIM model. Further implications of the proposed magnetic emission mechanism in the analysis of SGR activity can provide better understanding of neutron star crust, in particular, strengths and evolution of magnetic fields.

[1] V.N. Kondratyev, Phys.Rev.Lett. **88,** 221101 (2002); J.Phys.CS **248,** 012027 (2002); PhANE **4,** 1102 (2013)

Coulomb penetration and nuclear transmutations at sub-barrier reactions

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Many features of stellar evolution are mostly determined by nuclear reactions below the Coulomb barrier. Barrier penetrability and nuclear virtual process give main components of such reactions. The Trojan Horse Method [1,2] represents a useful framework for experimental test of the nuclear virtual reaction. Making use of such an approach we reveal deeply sub-barrier (p,x) reaction cross sections from quasi-free (d,nx) reaction data. Coulomb barrier penetration coefficient is calculated while taking into account the finiteness of nuclear potential of various shapes. In this contribution we analyze these components for nuclear processes important for Li/Be/B abundances, cf. [3,4] and refs. therein.

[1] C. Spitaleri, *Proceedings of the Fifth Winter School on Hadronic Physics*, Folgaria(Trento) Italy, Feb 1990, Problems of Fundamental Modern Physics II, p. 21-36, World Scientific 1990

[2] S. Cherubini et al., ApJ **457**, 855 (1996)

[3] L. Lamia et al., J. of Physics G -Nucl. and Part. Physics, **39**, 015106 (2012)

[4] R.E. Tribble, et al., Rep. Prog. Phys. **77**, 106901 (2014)

Preliminary studies for three experiments at Treiman-Yang criterion

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Nuclear reactions with three bodies in their final state may proceed through different reaction mechanisms. [1] The Feynman graph technique has been widely used to describe such reactions. However, it is very difficult in general to select the graphs that dominate a given process. The Treiman-Yang criterion is one of the most powerful experimental tests for verifying the pole approximation prediction when describing a quasi-free reaction mechanism[2]. We propose the theoretical study of the $^{2}H(^{10}B,\ ^{7}Be\ \alpha)n_s$, $^{1}H(^{11}B,\ \alpha_1\ \alpha_2)\alpha_s$, $^{3}He(^{9}Be,\ \alpha_1\ \alpha_2)\alpha_s$ reactions at different energies. The preliminary study help to check the existence of a QF channel by using the TY creterion.

[1] R.Tribble, C. Bertulani, M. La Cognata, A. Mukhamedzhanov, C. Spitaleri, *Indirect techniques in nuclear astrophysic,* Rep. Prog. Phys. **77** (2014) 106901 (49pp).
[2] S. B. Treiman and C. N. Yang, Phys. Rev. Lett. 8 (1962) 140.

Nuclear Reactions in Laser Plasmas

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Plasma is by far the most common form of matter known. Plasma in the stars and in the tenuous space between them makes up over 99% of the visible universe and perhaps most of that which is not visible. Given its nature, the plasma state is characterized by a complexity that exceeds that exhibited in the ordinary states, solid, liquid, and gaseous. Correspondingly, the physical properties of nuclear matter, e.g. structure, life times, reaction mechanisms etc., could be changed inside the plasma. The future availability of high-intensity laser facilities (ELI-NP, Extreme Light Infrastructure for Nuclear Physics) capable of delivering tens of peta-watts of power into small volumes of matter at high repetition rates will give the unique opportunity to investigate nuclear reactions and fundamental interactions under the extreme plasma conditions. ELI-NP will be one of the three pillars of ELI, which will host a very high intensity laser, where beams from two 10 PW lasers are coherently added to get intensities of the order of 10^{23} - 10^{24} W/cm^2. In the frame of cases of study we are proposing the construction of a general-purpose experimental set-up where will be possible to study the electronic screening problem in a wide variety of cases and configurations with different purposes. In particular we propose to study the screening effects on the low energy fusion reactions and on the weakly bound nuclear states (Hoyle, etc.). We propose a configuration based on two laser beams generating two colliding plasmas [1, 2]. The activity requires the construction of a highly segmented detection system for neutrons and charged particles. The segmentation is required in order to reconstruct the reaction's kinematic, thus getting information on the centre of mass energy dependence of the nuclear cross-sections. The "ideal" neutron detection module must have: high efficiency, good discrimination of gammas from neutrons, good timing performance for ToF neutron energies reconstruction. Moreover, it must be able to work in hard environmental conditions, like the ones established in the laser-matter interaction area. An R&D activity is planned also on SiC detectors, in collaboration with CNR-IMM Catania, in order to realize a wall device to detect charged particles in coincidence with neutrons. In the contribution we will reports on the project status.

[1] D. Mascali et al., Rad. Eff. and Def. in Sol. 165, Issue 6-10, 730 (2010)
[2] C. Labaune et al., Nature Comm., art. n.2506, DOI: 10.1038/ncomms3506 (2013)

Probing dynamics of fusion reactions through cross-section and spin distribution measurement

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The difference between the fusion dynamics of the symmetric and the asymmetric systems is well established through the study of the light particle evaporation spectra [1,2]. These studies concluded that the spectra for mass symmetric system show anomalous deviations from statistical model predictions which were explained in terms of the non-fusion of higher partial waves and existence of pre-equilibrium processes. However, these conclusions were made based on the analysis of single observable i.e. spectra only. The existence of fusion hindrance, if any, should be reflected in the cross-section and the spin distribution measurements as well. In order to have a better insight of this picture we have performed cross-section and spin distribution measurements for ^{16}O+^{64}Zn (asymmetric system) and ^{32}S+^{48}Ti (symmetric system) populating ^{80}Sr. The measurements have been performed using HIRA facility and BGO array at IUAC, New Delhi. The experimental cross-sections were well explained by the CCDEF [3] and TDHF [4] calculations within an uncertainty of 16%, thereby not giving any direct evidence of fusion hindrance. The experimental spin distributions were obtained by unfolding the experimental data to obtain angular momentum distributions with corrections from the statistical model calculations. The experimental spin distributions have been compared with the CCDEF calculations and were given as an input to the PACE code. The resulting theoretical α-spectrum reasonably explained the deviations in the experimental α-particle spectrum for the system ^{32}S+^{48}Ti [1] indicating the importance of shape of the spin distribution. Therefore we conclude that the shape of the spin distribution can act as a sensitive tool for the investigation of fusion dynamics.

[1] J. KAUR *et al.*, Phys. Rev. C **70**, 017601 (2004). [2] A. KUMAR *et al.*, Phys. Rev. C **68**, 034603 (2003). [3] J. FERNANDEZ NIELLO *et al.*, Comput. Phys. Commun. **54**, 409 (1989). [4] J. A. MARUHN *et al.*, Comput. Phys. Commun. **185**, 2195 (2014).

Statistical treatment of the decaying cascade of an excited nucleus - focus on the gamma emission down to the ground state

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Nuclear fission is a complex process and its description is a theoretical challenge. Several questions are still open such as the sharing of the total excitation energy between the fragments as well as their spin distribution. In this framework, experiments [1] were performed at ILL (Institut Laue-Langevin, Grenoble, France) with the EXILL setup to measure the prompt gamma-ray cascade related to the de-excitation of fission fragments. Is it possible to reach the characteristics of fission fragments at scission from the measurement of their gamma-ray cascade and, subsequently, to constrain the fission models?

To simulate the de-excitation phase of the fission fragments we used an upgraded version of the code Kewpie2 [2]. The latter handles the competition between light particles evaporation, fission and gamma-ray emission using classic statistical formalisms, i.e. Weisskopf-Ewing or Hauser-Feshbach for light particles evaporation, Bohr-Wheeler for fission and, Weisskopf for gamma-ray emission. As Kewpie2 was initially devoted to the decay of heavy and super-heavy nuclei, a specific scheme based on Bateman equations was developed to take account of very small probabilities. It allows computing both statistical and dynamical observables such as the survival probability of a decaying nucleus [3] and the fission time distribution [4].

In order to further constrain the statistical code with the new experimental data discussed above, several modifications were made on Kewpie2 to simulate the whole gamma-ray cascade down to the ground state. It requires the implementation of the nuclear level schemes, the improvement of the gamma decay with gamma strength functions, the treatment of the coupling from continuum to discrete levels as well as the whole spin distribution… Kewpie2 permits also to incorporate physics coming from microscopic models like level densities which are the most important physical ingredients of statistical formalisms.

We will present the code Kewpie2 and the physicals ingredients needed for the statistical formalisms. Then, the various improvements made to treat the whole gamma-rays cascade down to the ground state will be discussed. Finally, the results of Kewpie2 on the prompt-gamma cascade of fission fragments will be compared to experimental data.

[1] T. Materna *et al.*, Proc. of CGS15 (Dresden), to be published
[2] B. Bouriquet *et al.*, Comp. Phys. Comm. **159**, 1 (2004), H. Lu *et al.*, in preparation
[3] Y. Abe *et al.*, Int. J. Mod. Phys. E **16**, 491 (2007)
[4] D. Boilley *et al.*, Int. J. Mod. Phys. E **17**, 1681 (2008)

Competition of kaon and hyperon mixture in nuclear matter

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It is well-known that mixture of hyperons and kaons in nuclear matter cause softening of matter due to a strong attraction or increased number of degree of freedom. This softening is one of the most serious problems in nuclear physics since one has to sustain an observed heavy neutron star with twice the solar mass. On the other hand, we have investigated the competition of kaon and hyperon mixture in nuclei [1]. Then we found that all the kaons put in nuclei are absorbed in nucleons and converted into hyperons. In this presentation we discuss the competition between kaons and hyperons in nucleaer matter in the core of neutron stars. We also discuss the effect of degenerate electrons and inhomogeneous structures of matter.

[1] T. Muto, T. Maruyama, and T. Tatsumi, EPJ Web Conf. **73** (2014) 05007

TRACE and GASPARD: direct reactions with AGATA@SPES

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The TRACE [1, 2] and GASPARD [3, 4] high-granularity silicon arrays have been natively designed for optimal integration in new generation gamma detectors such as AGATA with the aim of performing high-resolution structure and reaction studies. Indeed, the coupling to AGATA [5] allows a very large gain in excitation energy resolution, in comparison with the case where the excitation energy is deduced from the recoil charged-particle measurement. The TRACE and GASPARD collaboration are now converging to build such new-generation Si ensemble in common, with a timeline of 2019-20 for completion of the final 4π array, ready for the emerging ISOL facilities, like SPES and SPIRAL2. Recently, a project of intermediate configuration of silicon array (named MUGAST for MUST2- GASPARD-TRACE) allowing reaction studies in combination with AGATA at VAMOS has been proposed. Timeline for this project is beginning of 2017. The contribution focuses on the progresses of the common project.

[1] D.Mengoni *et al.*, Nucl. Inst. and Meth. A 764 (2014) 241. [2] A. Gadea *et al.*, Nucl. Inst. and Meth. A 654 (2011) 88. [3] D. Beaumel, Nucl. Inst. and Meth. B 317 (2013) 661. [4] M.Assié *et al.*, Eur. Phys. Jour. A 51 (2015), 11. [5] S. Akkoyun *et al.*, Nucl. Inst. and Meth. A 668 (2012) 26.

Elastic scattering of ^{9}Be+^{51}V near the Coulomb barrier

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We present the elastic scattering angular distributions of the ^{9}Be + ^{51}V system measured at two energies near the Coulomb barrier, $E_{\rm lab}$ = 17.44 and 18.53 MeV. The measurements were performed with the tandem Van de Graaff at the National Institute for Nuclear Research in Mexico. The theoretical analysis was made within the semimicroscopic optical model [1] that combines a microscopic calculation of the mean-field double folding potential and a phenomenological construction of the dynamical polarization potential. Calculations reproduced the elastic-scattering data very well and the total reaction cross sections were deduced. Comparison was made with the same calculations carried out using the Sao Paulo potential.

In order to check the consistency of our results with those for other systems with the same projectile (the left-hand panel of Fig. 1), we have compared our results with the data previously reported using a data reduction as proposed, for instance, in [2]. The reduced total reaction cross sections obtained for different systems having the same projectile show perfect consistency. On the other hand, our results are consistent with the reduced total reaction cross sections obtained for the other system, which has the ^{7}Be isotope as a projectile. Thus we conclude that our results show a good agreement in comparison with the similar nuclear systems.

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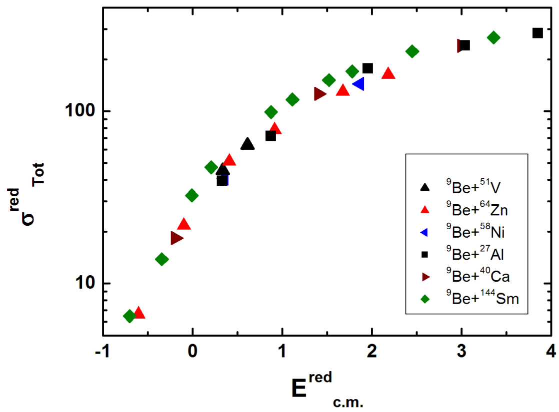

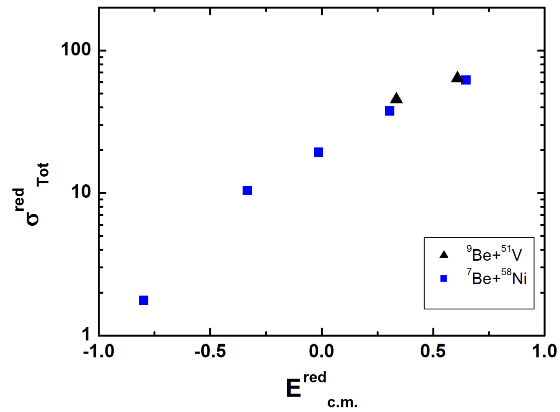

Fig.1 The reduced total reaction cross sections: the left-hand panel shows different systems with the ^{9}Be projectile; the right-hand panel compares ^{9}Be + ^{51}V and ^{7}Be + ^{58}Ni systems.

[1] S. A. Goncharov *et al.*, Phys. At. Nucl. **70**, 1 (2007) 18.
[2] P. R. S. Gomes *et al.*, J. Phys.: Conf. Ser. **492**, 012004 (2014).

Properties of quark matter and structure of compact stars in the perturbation model with a rapidly convergent matching-invariant running coupling

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The properties of dense quark matter are investigated in the perturbation theory with a rapidly convergent matching-invariant running coupling constant. The fast convergent speed is mainly due to the resummation of an infinite number of known logarithmic terms in a compact form. The only parameter in this model, the ratio of the renormalization subtraction point to the chemical potential, is restricted to be about 2.64 according to the Witten-Bodmer conjecture, which gives the maximum mass and the biggest radius of quark stars to be, respectively, two times the solar mass and 11.7 kilometers..

Pairing induced fluctuations studied through giant dipole resonance

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The study of nuclear properties at finite temperature (T) has been an interesting area in nuclear physics. Due to the recent developments in the experimental facilities, it is now possible to measure certain properties at very low-T mainly through the giant dipole resonance (GDR). The GDR has been proved to be a unique tool to study the structure of hot nuclei. The behavior of nuclei at very low temperatures is one among such area where the experimental results are scarce. This is the region where the shell effects and pairing effects are still active though being strongly modified by the thermal effects. The understanding of phase transitions in hot nuclei which are not clearly understood so far.

The thermal shape fluctuation model (TSFM) based on the macroscopic approach is one among the most successful models to explain several GDR observations in hot and rotating nuclei [1-2]. The TSFM describes the measured GDR observable through an average over the probable quadrupole shapes. However, this model fails to explain the GDR width at low-T [3–4]. The first low-T GDR data reported in Ref. [5] was successfully explained in a microscopic model by incorporating pairing within the modified BCS approach [6]. This has been confirmed later by using thermal pairing obtained from a microscopic approach that includes quasiparticle number fluctuations in the thermal BCS pairing gap [7]. This success prompted us to include pairing correlations in TSFM [8-9] with which we could explain the low-T GDR data in ^{97}Tc and ^{120}Sn.

[1] P. Arumugam, A. G. Deb and S. K. Patra, Europhys. Lett. **70**, 313 (2005).
[2] P. Arumugam, G. Shanmugam, and S. K. Patra, Phys. Rev. C **69**, 054313 (2004).
[3] Deepak Pandit et al., Phys. Lett. B **713**, 434 (2012).
[4] Balaram Dey et al., Phys. Lett. B **731**, 92 (2014).
[5] P. Heckman et al., Phys. Lett. B **555**, 43 (2003).
[6] N. D. Dang and A. Arima, Phys. Rev. C **67**, 014304 (2003).
[7] N. Dinh Dang and N. Quang Hung, Phys. Rev. C **86**, 044333 (2012).
[8] A. K. Rhine Kumar, P. Arumugam and N. Dinh Dang, Phys. Rev. C **90**, 044308 (2014).
[9] A. K. Rhine Kumar and P. Arumugam, AIP Conf. Proc. **1524**, 113 (2013).

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Influence of Mass of the Fragmenting System on Projectile Multifragmentation Spectrum at Dubna Energy

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The multifragment decays of Mg projectiles after collisions with various emulsion targets at a bombarding energy of 4.5 AGeV has been studied. The bound charge Z_b, which is the sum of all the projectile fragments with charge $Z_{PF} \geq 2$, is considered to be one of the important observable in the study of projectile multifragmentation. Correlation between mean number of intermediate mass fragments $\langle N_{IMF} \rangle$ and Z_b is one of the most interesting aspects of studying projectile multifragmentation. In this report an attempt has been made to study the variation of $\langle N_{IMF} \rangle$ on the mass of the fragmenting system Z_b for Mg-Em interaction at 4.5 AGeV. A rise and fall pattern in $\langle N_{IMF} \rangle$ vs Z_b plot with the maximum value of $\langle N_{IMF} \rangle$ corresponding to the value of Z_b = 6-7 is observed for the Mg-Em system. The value of bound charge corresponding to the maximum value of average number of intermediate mass fragments is found to be consistent with the results reported by ALADIN group[1-5]. The variation of $\langle N_{IMF} \rangle$ on Z_b normalized with the projectile charge Z_p indicates a clear size effect for the studied systems.

[1] J. HUBELE *et al.*, Z.Phys. A340, (1991)
[2] P. KREUTZ *et al.*, Nucl. Phys. A556, (1993)
[3] P.L.JAIN *et al.*, Phys. Rev. C50, 2 (1994)
[4] M.L.CHERRY *et al.*, Phys. Rev. C52, (1995)
[5] A. SCHUTTAUF *et al.*, Nucl. Phys. A607, (1996)

Exploring the high spin states of ^{88}Zr

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Understanding of the complex structure and dynamics of a nuclear system requires investigation of motion of the constituent nucleons and their mutual interactions. The high spin states of a nucleus near shell closure provide unique test bench for exclusively studying the excitations of the valence shell nucleons in the nuclear mean field and the residual interactions. In addition, a number of interesting phenomena are observed in doubly closed shell nuclei, like, the evolution of collectivity and presence of high spin isomers, to mention a few [1]. Nuclei around ^{90}Zr having $Z = 40$ sub-shell closure and $N = 50$ major shell closure are perfect candidates to probe these emergent phenomena [2]. Recently, the high spin states of ^{88}Zr were populated with ^{13}C(^{80}Se,5n) reaction using ^{13}C beam at 60 MeV from TIFR-BARC pelletron facility [3]. The γ-rays emitted from the residual nuclei were detected using 18 Compton suppressed clover HPGe array, know as INGA [4]. The energy, spin and parity of several states of ^{88}Zr have been assigned. The results have been compared with large scale shell model calculations for full unrestricted f_5pg_9 model space using two recently developed interactions JUN45 [5] and jj44b [6]. Although, there are overall good agreement between the calculated and the experimental results, at high spin their differences have been observed to be increased. To explore further higher spin states a more symmetric reaction was performed using ^{30}Si beam and ^{65}Cu target at 137 MeV. A number of high energy transitions have been observed indicating contribution from particle excitation across the 50 shell gap. In this conference, the spectroscopic study of ^{88}Zr produced using the two different reactions will be presented and the results will be interpreted using large scale shell model calculations.

References

[1] K. Heyde and J. L. Wood, Rev. Mod. Phys. **83** (2011) 1467.

[2] S. Saha *et al.*, Phys. Rev. C **86** (2012) 034315.

[3] S. Saha *et al.*, Phys. Rev. C **89** (2014) 044315.

[4] R. Palit *et al.*, Nucl. Instrum. Methods A **680** (2012) 90.

[5] M. Honma, T. Otsuka, T. Mizusaki and M Hojorth-Jensen, Phys. Rev. C **80** (2009) 064323.

[6] B. A. Brown and A. F. Lisetski (unpublished).

Effect of deformations and orientations in ^{100}Sn daughter radioactivity

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The phenomenon of cluster radioactivity, i.e., the spontaneous emissions of fragments heavier than alpha particle, is now well established on experimental as well as theoretical front. Many neutron-rich clusters ranging from ^{14}C to ^{34}Si have been observed from ^{221}Fr to ^{242}Cm parent nuclei. In all these decays, observed in trans-lead region, the daughter nucleus is always ^{208}Pb (a doubly closed shell nucleus) or its neighboring nucleus and hence this phenomena has been cited in literature as "lead radioactivity". Stressing the importance of shell effects, Gupta and collaborators [1] studied the cluster decays of the neutron-deficient $^{108-116}$Xe, $^{112-120}$Ba, $^{116-124}$Ce, $^{120-124}$Nd, $^{124-128}$Sm, and $^{128-132}$Gd parents in order to explore the region of possible Sn radioactivity. This study, using the preformed cluster model (PCM) indicates the possible decay of ^{8}Be from ^{108}Xe, ^{12}C from ^{112}Ba, ^{16}O from ^{116}Ce, etc., giving rise to the doubly magic ^{100}Sn (Z=N=50) daughter. However in their later work [2] for neutron-rich isotopes ^{146}Ba, ^{152}Ce, ^{156}Nd, ^{160}Sm and ^{164}Gd, it was observed that non-α like clusters are preferred for decays into ^{132}Sn daughter nucleus, though less probable than A = 4n α-nuclei clusters in the case of ^{100}Sn daughter radioactivity.

Since the shape of a nucleus provides an intuitive understanding of the spatial density distributions, therefore, together with shell effects, it is expected that nuclear deformations and orientations should play an important role in context of ^{100}Sn radioactivity. In order to look for such effects, we intend to analyze the above study [1] using PCM to investigate the role of spherical as well as quadrupole (β_2) deformations on the behavior of possible fragmentations of Xe to Gd parents. Note that the effect of deformations and orientations was studied [3] in cluster decays of various radioactive nuclei from the trans-lead region, so we are encouraged to explore the same in the trans-tin region. It is relevant to mention here that all the parents $^{108-116}$Xe, $^{112-120}$Ba, $^{116-124}$Ce, $^{120-124}$Nd, $^{124-128}$Sm, and $^{128-132}$Gd and their respective emitted clusters ^{8}Be, ^{12}C, ^{16}O, ^{20}Ne, ^{24}Mg and ^{28}Si considered here are deformed and hence the deformation effects seem indispensable which were not analyzed explicitly in the earlier work [1,2]. Note that the orientations are 'optimized' (uniquely fixed) on the basis of β_{2i} alone which manifests in the form of "hot (compact)" and "cold (non-compact)" configuration. Whereas the 'hot compact' configuration corresponds to smallest interaction radius and highest barrier, the 'cold non-compact' configuration corresponds to largest interaction radius and lowest barrier. Using PCM, we observe that there is no significant change in potential energy surface (PES) for the choice of either spherical or 'cold non-compact' configuration, however deep minima are observed for many clusters in the case of 'hot compact' configuration. One may conclude that proper understanding of nuclear shapes along with the relative orientations is essential to make concrete and explicit predictions. As an extension of this work, it will be interesting to see the effect of higher multipole deformations alongwith possible role of different proximity interactions in reference to Sn daughter radioactivity.

[1] S. Kumar *et al.*, Phys. Rev. C **51**, 1762 (1995).
[2] S. Kumar *et al.*, J. Phys. G: Nucl. Part. Phys. **22**, 215 (1996).
[3] G. Sawhney *et al.*, Phys. Rev. C **83**, 064610 (2011).

Resonance strength measurement at astrophysical energies: the ^{17}O(p,α)^{14}N reaction studied via THM

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Resonance reactions play a decisive role in many astrophysical contexts. Indeed, a resonance might dramatically enhance the astrophysical S(E)-factor so, when a resonance is present right at astrophysical energies, its measurement is crucial to pin down the astrophysical scenario. Unknown or unpredicted resonances might introduce large systematic errors in nucleosynthesis models. These considerations apply to low energy resonances and to sub-threshold resonances as well, as they may produce sizable modifications of the S-factor due to, for instance, destructive interference with another resonance [1,2].
In recent years, the Trojan Horse Method (THM)[3-10] has been used to investigate the low-energy cross sections of proton-induced reactions on ^{17}O nuclei, overcoming extrapolation procedures and enhancement effects due to electron screening. In particular, the strengths of the 65 keV resonance in the ^{17}O(p,α)^{14}N reaction has been extracted and it has been used for calculating the strength for the (p,γ) reaction channel. We will report on the indirect study of the ^{17}O(p,α)^{14}N reaction via the THM by applying the approach recently developed for extracting the resonance strength of narrow resonance in the ultra-low energy region. Two measurements will be discussed, focusing on the data analysis procedure and on the quasi-free (QF) reaction mechanism selection.

[1] C. Rolfs and W. Rodney "Cauldrons in the Cosmos", The University of Chicago Press, Chicago, (1988).
[2] C. Iliadis "Nuclear Physics of Stars", Wiley-VCH (2007).
[3] M.L. Sergi *et al.*, Phys. Rev. C **82**, 0322801(R) (2010).
[4] M.L. Sergi *et al.*, approved for pubblication on Phys. Rev. C.
[5] M. La Cognata *et al.*, Astr. Phys. Journ. Lett. **739**, L54 (2011).
[6] C. Spitaleri *et al.*, Phys. Rev. C, **90**, 035801 (2014)
[7] L. Lamia L.*et al.*, The Astrophys. Journ. **768**, 65 (2013).
[8] R.G. Pizzone *et al.*, Phys. Rev. C **83**, 045801 (2011).
[9] M.L. Sergi, Il nuovo Cimento **125 B**, N.4, 457 (2010).
[10] R. Tribble *et al.*, Rep. Prog. Phys. **77**, 106901 (2014).

Understanding the effect of channel coupling on fusion of ^{6}Li+^{64}Ni

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A recent measurement of total fusion (TF) and complete fusion (CF) cross sections of weakly bound stable projectile ^{6}Li with lower medium mass target ^{64}Ni have shown an average suppression of 13% compared to the one dimensional barrier penetration model (1DBPM) at above barrier energies [1]. At below the barrier energies both TF and CF cross sections are enhanced in comparison with the 1DBPM prediction. While the above barrier suppression of CF is attributed to breakup, the origin of enhancements of TF and CF are not clearly understood.

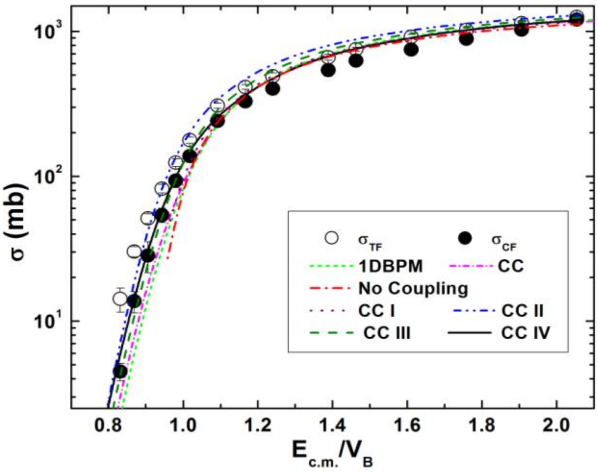

FIG.1 Fusion excitation function of the system ^{6}Li+^{64}Ni for various coupling configuration with the data.

We intend to present an attempt to understand the origin of the fusion cross section enhancement for ^{6}Li+^{64}Ni system at below barrier energies within the frame work of Coupled Reaction Channel (CRC) model. The code FRESCO [2] has been used to investigate the effect of coupling of individual reaction channels. Four different coupling conditions, *viz,* inelastic excitation of target and projectile (CC I), CC I plus 1n stripping (Q =0.435 MeV) leading to the 3-body final state (CC II), CC I plus 1p stripping (Q =3.021 MeV) again leading to the 3-body final state (CC III) and CC I plus both 1n and 1p stripping channels (CC IV) have been used. A real potential of double folded M3Y interaction and an imaginary potential of very short range have been used as the bare potential. Well known Akyuz-Winther type potential has been used for transfer channels. The details of the coupling scheme can be found in Ref. [3]. Results of the model calculations are shown in Fig. 1. Interpretation of the results will be presented in the conference.

[1] Md. Moin Shaikh *et. al.,* Phys. Rev. C **90**, 024615 (2014).
[2] I. J. Thompson, Comp. Phys. Rep. **7**, 167 (1988).
[3] Md. Moin Shaikh *et. al., Communicated to* Phys. Rev. C.

Exchange Effects in the Radiative Capture Reactions $^{3}H(\alpha,\gamma)^{7}Li$ and $^{3}He(\alpha,\gamma)^{7}Be$ at Astrophysical Low and Medium Energies

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The radiative capture reactions at astrophysical low energies play an important role for nuclear astrophysics [1, 2]. In the most cases the cross sections of these reactions at such energies are inaccessible for reliable experimental measurements because of the strong Coulomb repulsion. Calculations based on fully microscopic approaches also present sufficiently difficult computational problem due to the antisymmetrization. Thus, the construction of reliable approximations in the framework of these approaches is rather topical problem [3–5].

In the present work the mirror radiative capture reactions $^{3}H(\alpha,\gamma)^{7}Li$ and $^{3}He(\alpha,\gamma)^{7}Be$ are considered with and without exchange effects. The promising approach [6, 7] based on the algebraic version of the resonating group model [8] is adopted as a specific one for calculations. This model uses the expansions over the basis of the oscillator functions. It allows to perform, largely, the analytical calculations and controlled numerical ones. It is shown, that exchange terms of the Coulomb interaction affect the energy dependence of astrophysical S-factors of the considered reactions insignificantly. Exchange terms of the nuclear interaction are important and their truncation can lead to a qualitative change of the energy behavior of the astrophysical S-factors. It is found, that slight redefinition of the effective microscopic nuclear potential makes it possible to describe the recent experimental S-factors data for the $^{3}H(\alpha,\gamma)^{7}Li$ and $^{3}He(\alpha,\gamma)^{7}Be$ reactions (see [1, 2] and references therein) well.

[1] E.G. Adelberger *et al.*, Rev. Mod. Phys. **83**, 195 (2011)
[2] Y. Xu *et al.*, Nucl. Phys. A **918**, 61 (2013)
[3] S.Yu. Igashov *et al.*, Bull. Russ. Acad. Sci.: Phys. **73**, 756 (2009)
[4] S.Yu. Igashov *et al.*, Bull. Russ. Acad. Sci.: Phys. **74**, 1608 (2010)
[5] S.Yu. Igashov, Yu.M. Tchuvil’sky, Phys. Atom. Nucl. **74**, 1588 (2011)
[6] A.S. Solovyev *et al.*, J. Phys.: Conf. Ser. **569**, 012020 (2014)
[7] A.S. Solovyev *et al.*, Eur. Phys. J.: Web Conf. **86**, 00054 (2015)
[8] G.F. Filippov, I.P. Okhrimenko, Sov. J. Nucl. Phys. **32**, 480 (1980)

Elastic scattering of ^{17}O ions from ^{58}Ni at near-barrier energies

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[7] *DF, Università di Milano, Italy* [8] *INFN - LNL, Legnaro (PD), Italy*
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A powerful tool for the study of weakly bound nuclei is the elastic scattering process, which provides a first information on the overall reactivity of the collision participants. We measured the elastic scattering angular distributions for the reaction ^{17}O+^{58}Ni in order to compare the reactivity of ^{17}O (S_n= 4.143 MeV) with its mirror nucleus ^{17}F (S_p= 0.600 MeV). The experiment was performed at the Laboratori Nazionali di Legnaro with an ^{17}O beam in the energy range 40.0÷50.0 MeV impinging on a ^{58}Ni (150 μg/cm^2) target with a ^{208}Pb (50 μg/cm^2) backing. Three E_{res} DSSSDs modules of the EXPADES [1] array where placed at ±50° (45° < θ_{CM} <80°) and +110° (111° < θ_{CM} <140°). Data were analyzed within the frame of the Optical Model using both Woods-Saxon and M3Y double-folding potentials. Fig. 1 shows the elastic scattering angular distributions and the optical model best fits for the two approaches. The resulting fit parameters agree with a model describing the ^{17}O nucleus as a ^{16}O core with a valence neutron orbiting in a $d_{\frac{5}{2}}$ state [2]. The reduced total reaction cross sections, shown in the inset of Fig. 1, result to be slightly lower than those of ^{16}O+^{58}Ni system [3], but higher than those of ^{17}F+^{58}Ni system [4]. This outcome suggests that, for the pair ^{17}O-^{17}F, nuclear structure effects play a more relevant role than the projectile binding energy in the reaction dynamics at Coulomb barrier energies.

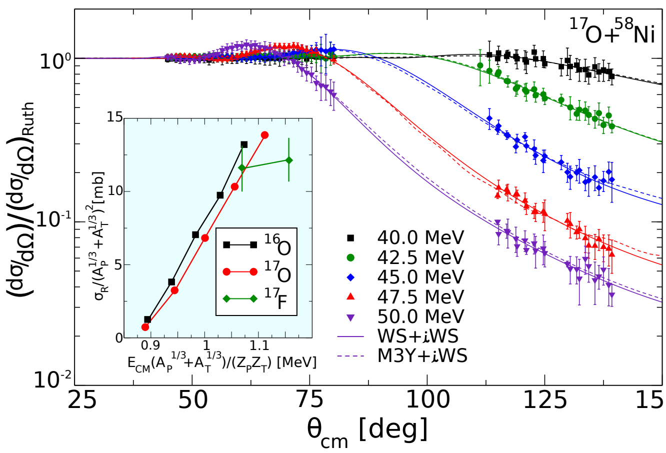

Figure 1: Elastic scattering angular distributions for the ^{17}O+^{58}Ni collision at 5 energies in the laboratory frame. WS and M3Y indicates the Woods-Saxon and M3Y Double-folding potential, respectively.

[1] E. Strano *et al.*, Nucl. Instr. and Meth. B **317** 657 (2013).
[2] S. A. Coon, L. Jaqua, Phys. Rev. C **44** 1 (1991).
[3] N. Keeley *et al.*, Nucl. Phys. A **582** 314 (1995).
[4] M. Mazzocco *et al.*, Phys. Rev. C **82** 054604 (2010).

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Coupling of α- and t-cluster structures in excited deformed states of ^{35}Cl

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Clustering is a many-body correlation and important to understand nuclear structures and reactions. Recently, cluster correlations in deformed states of sd-shell nuclei have been discussed[1] but it is an open problem which cluster structure is coupled in each deformed state. One rule of types of cluster structures coupled in deformed states is the threshold energy rule[2]. In the threshold energy rule, cluster structures are realized systematically near the threshold energy. The threshold energy rule works for very light self-conjugate $4N$ nuclei in $A \lesssim 20$ region but studies of the rule are insufficient for $N \neq Z$ or sd-shell nuclei. Another rule is similarity of particle-hole configurations of deformed states and cluster structures. In the spherical shell-model picture, deformed states have many-particle-many-hole (mp-mh) configurations, and cluster structures also contain mp-mh components. When particle-hole configurations of deformed and cluster structures are similar, those states are expected to be coupled.

In ^{35}Cl, negative-parity deformed states have been observed, and the observed deformed states are suggested to have α-^{31}P cluster structure[3]. However, the suggestion is based on just indirect discussion, and there is no theoretical study of cluster structures in the negative-parity deformed states of ^{35}Cl. This study aims to clarify structures of excited states in ^{35}Cl focusing on cluster structures theoretically.

In this study, structures in excited states of ^{35}Cl are investigated by using the antisymmetrized molecular dynamics (AMD)[4] and the generator coordinate method (GCM). As GCM basis, wave functions of deformed structures and α-^{31}P and t-^{32}S cluster structures are adopted. Trial wave functions are AMD wave functions, and the GCM basis are obtained by using energy variational calculations with two kinds of constraint, which are quadrupole deformation parameter β and intercluster distance[5] for deformed structures and cluster structures, respectively.

By the GCM calculation, various rotational bands are obtained. In negative-parity deformed states, α-^{31}P and t-^{32}S cluster structures are coupled although threshold energies of $\alpha + {}^{31}$P and $t + {}^{32}$S are much different, which are 6.5 MeV and 18 MeV for $\alpha + {}^{31}$P and $t + {}^{32}$S, respectively. The negative-parity deformed states have $3\hbar\omega$ excited configurations dominantly in the spherical shell-model picture, and α-^{31}P and t-^{32}S cluster structures can have $3\hbar\omega$ configurations when intercluster distances are small. This results show that particle-hole configurations of deformed structures and cluster structures with small intercluster distance are important for coupling of deformed states and cluster states although the threshold energy rule is inconsistent with the results.

[1] for example, Y. Taniguchi, Y. Kanada-En'yo, and M. Kimura, Phys. Rev. C **80**, 044316 (2009).
[2] H. Horiuchi, K. Ikeda, and Y. Suzuki, Prog. Theor. Phys. Suppl. **52**, 89 (1972).
[3] A. Bisoi *et al.*, Phys. Rev. C **88**, 034303 (2013).
[4] M. Kimura, Phys. Rev. C **69**, 044319 (2004).
[5] Y. Taniguchi, M. Kimura, and H. Horiuchi, Prog. Theor. Phys. **112**, 475 (2004).

The influence of atomic shell on decay properties of a nucleus

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The influence of the electronic surrounding (the electron shell of an atom or an ion) on the alpha decay widths was investigated in numerous papers. The results obtained in these works differ widely (even in sign) and the details of the approaches used for that sometimes are mutually contradictory. At the same time all these papers excluding [1] are based on the WKB approximation which does not take into account some effects of propagation of the alpha-particle wave. In paper [1] these effects were studied and turned out to be significant however the model of the electron shell was oversimplified in this investigation.

In the present work we demonstrate a direct quantum-mechanical approach to the problem. Many delicate effects such as the reflection of the wave in the classically-allowed area, boundary conditions of the alpha particle interacting with a screening nucleus, adiabaticity of alpha-particle motion in relation to the fast and diabaticity of it in relation to slow electrons, etc. are taken into account.

A similar study of the proton decay is carried out. The scale of this effect is of the same order as that typical for the alpha decay. However the influence of the atomic shell on the proton decay is distinct from that inherent in the alpha decay. Therefore the radioactive nuclei in which these two processes are in competition provide a chance to observe the discussed effect of the atomic shell by measuring of the branching ratio of the processes in the case that secondary beams of these nuclei produced via in-flight method would be utilized.

1. Igashov S.Yu, Tchuvil'sky Yu. M. *Phys. At. Nucl.* **76**, 1452 (2013).

Determination of integral cross sections of ^{3}H in Al foils monitors irradiated by protons with energies 40 to 2600 MeV

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ABSTRACT

The results of determination of ^{3}H in ^{27}Al foils monitors (thickness 0.0513 g /cm^2) are presented. These foils have been irradiated together with foils of ^{56}Fe (thickness ~ 0.3953 g /cm^2) and ^{nat}Cr (thickness ~ 0.3323 g /cm^2) by protons of different energies. The diameters of all the foils were 10.5 mm. For their geometric alignment for irradiation the foils have been placed in 15x15 mm polyethylene bags of 150 μm thickness. That means protons with energies 2600 and 1600 MeV bombarded the experimental samples in the form of individual sandwiches CH_2 + Fe + Al + CH_2 and CH_2 + Cr + Al + CH_2, while protons with energies 1200 , 800, 600, 400, 250, 150, 100, 70 and 40 MeV irradiated doublesandwiches CH_2 + Fe + Al + CH_2 + CH_2 + Cr + Al + CH_2. The irradiation was carried out at the ITEP accelerator U-10 under ISTC Project 3266 in 2006 -2009. ^{3}H has been extracted from Al foils using A307 Sample Oxidizer. Ultra low level liquid scintillation spectrometer Quantulus1220 was used to measure the ^{3}H activity and SpectraDec software package was applied for processing measured β-spectra.

The values of the ^{27}Al(p,x)^{3}H reaction cross sections obtained in these experiments are being compared with data measured earlier and with results of simulations by MCNP6 radiation transport code using CEM03.03 event generator.

Thanks to modern high-energy transport codes simulate transport of ^{3}H as an individual particle, all experiments have been modeled in the actual geometry and composition of the sandwiches. This approach allows to calculate the integral cross sections for the ^{3}H with accounting of a balance between losses of ^{3}H born in Al foils and its feeding from CH_2+ Fe or CH_2 + Cr.

Elastic scattering of $^{17}O+^{208}Pb$ at energies near the Coulomb barrier.

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In the last decades the study of the reaction mechanisms at energies around the Coulomb barrier for halo and weakly bound nuclei has attracted a large interest. The peculiar characteristics of these nuclei can affect deeply their reaction dynamics increasing or enhancing the total reaction cross section and/or specific reaction channels (for instance, breakup, transfer, fusion).

Thus, it is quite important to have a large and reliable systematics of reaction cross section measurements for stable nuclei interacting with light, medium and heavy targets in order to compare the behavior of exotic nuclei with that of stable and strongly bound nuclei.

We measured at the Laboratori Nazionali di Legnaro the elastic scattering process for the system $^{17}O+^{208}Pb$ in the energy range 80 - 87 MeV. This measurement, performed within the commissioning of the detection system EXPADES [1], is particularly relevant since ^{17}O is the mirror nucleus of the radioactive and weakly-bound projectile ^{17}F (S_p = 0.6 MeV). The elastic scattering angular distributions were analyzed within the framework of the optical model using the code FRESCO [2] to extract the total reaction cross section. The data will be compared with those obtained for the neighboring systems $^{16,18}O+^{208}Pb$ and others available in literature [3].

[1] E. Strano et al., Nucl. Instr. and Meth. B **317,** 657 (2013).
[2] I.J. Thompson, Comput. Phys. Rep. **2**, 167 (1998).
[3] N. Keeley, K.W. Kemper and K. Rusek, Eur. Phys. J. A **50,** 145 (2014) and references therein.

Configuration-Space Monte-Carlo Approach to Problem of Pairing in Nuclei

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Pairing correlations and pair scattering into the continuum of reaction states play a decisive role in determining nuclear drip-lines, binding energies, and many collective properties. In this presentation we put forward a new Configuration-Space Monte-Carlo (CSMC) method for treating large-scale nuclear pairing problems.

In the CSMC method the Hamiltonian matrix is stochastically generated in Krylov subspace, resulting in the Monte-Carlo version of Lanczos-like diagonalization. The advantages of using this approach include the absence of the fermionic sign problem, probabilistic interpretation of quantum-mechanical amplitudes, and the ability to handle truly large-scale problems with a defined precision and error control.

The features of our CSMC implementation will be shown using model and realistic examples. Special attention is given to difficult limits: situations with non-constant pairing strengths, cases with nearly degenerate excited states, limits where pairing correlations in finite systems are weak, and problems in which the relevant configuration space is large. Large-scale study of pairing correlations is demonstrated using a model of ^{24}O that includes a continuum of scattering states.

This presentation is based upon work supported by the U.S. Department of Energy Office of Science, Office of Nuclear Physics under Award Number DE-SC0009883.

Search for High Energy Alpha Particles in the Reactions of 7.5AMeV 197Au with 232Th

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The search for alternative reaction paths for heavy element production requires a careful experimental investigation of mechanisms other than fusion, e.g., multi-nucleon transfer or very asymmetric fission of even heavier transient systems. Many super heavy elements are expected to decay by alpha particle emission. The heaviest elements are characterized by unusually high alpha particle energies which distinguish them (in general) from the lighter elements. Using 197Au projectiles incident on a 232Th target, we are pursuing survey experiments based upon the implantation of recoiling heavy reaction products in an array of fast plastic scintillators and the detection of alpha particle decays characteristic of these heavy nuclei. The 7.5 MeV/nucleon 197Au beam was pulsed for different time intervals in order to be able to identify species with different half-lives. A large number of interesting high alpha-energy activities were detected both in-beam and out of beam. These data will be discussed, as will extensions of this method.

Lambda Polarization in Energetic Peripheral Heavy Ion Collisions

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Recent publications have addressed the issue of vorticity in peripheral, relativistic heavy ion collisions at NICA and FAIR energies [1]. In reference [2], the Lambda polarization in ultra-relativistic heavy ion collisions was studied. This presentation focuses on polarization of lambda and anti-lambda hyperons in peripheral heavy ion collisions at intermediate relativistic energies, based on the assumption of local thermodynamic equilibrium at freeze-out [3]. The polarization vector is proportional to the thermal vorticity field [3], and it is of the order of few percents. It is maximal for particles with moderately high momentum emitted in the reaction plane. A selective measurement of these particles could make lambda polarization detectable at FAIR and NICA energies.

[1] L.P. Csernai, D.J. Wang, M. Bleicher, and H. Stocker, Phys. Rev. C 90. 021904(R) (2014).
[2] V. Voronyuk, V.D. Toneev, W. Cassing, E.L. Bratkovskaya, V.P. Konchakovski, and S.A. Voloshin, Phys. Rev. C 83, 054911 (2011).
[3] F. Becattini, V. Chandra, L. Del Zanna, and E. Grossi, Ann. Phys. 338, 32 (2013).

The 12th International Conference on Nucleus-Nucleus Collisions, June 21-26, 2015, Catania, Italy

Projected total energy surface description for axial shape asymmetry in even-even nuclei

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The projected total energy surface (PTES) approach has been developed based on the triaxial projected shell model (TPSM) hybridized with the macroscopic–microscopic method. The total energy of an atomic nucleus is decomposed into macroscopic, microscopic and rotational terms. The macroscopic and microscopic components are described with the liquid drop model and Strutinsky method, respectively, and the rotational energy is given by the TPSM, the term beyond the mean field. To test theory, the PTES calculations have been carried out for the yrast states of the well deformed rare earth nuclei W, and the theoretical results are in good agreement with the experimental data. By using the equilibrium quardrupole deformations determined by the PTES, the calculation of the transition quardrupole moment (Qt) in function of spin also reproduces the experimental data. A comparison between the PTES and TRS methods has been made for theoretical and application uses.

Recent applications of nuclear track emulsion

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Featuring excellent sensitivity and spatial resolution nuclear track emulsion (NTE) maintains a position of universal and inexpensive detector for survey and exploratory research (http://becquerel.jinr.ru/). Automatic microscopes will enable one to approach at a new level to application of NTE.

Cluster aspects of structure of light nuclei are investigated in fragmentation of nuclei with energy 1.2 A GeV are studied in NTE exposed to secondary beams of the JINR Nuclotron. The charge topology of 11C dissociation is presented and compared with data on the nuclei 7Be, 8,10B, 9,10C and 14N. Probabilities of occurrence of a variety of ensembles of fragments allow one to reveal their structural weights.

When testing the novel NTE a variety of physics tasks related with measurements of alpha-particle tracks were addressed.

Decays of stopped 8He nuclei, breaking-ups of 12C nuclei by thermonuclear neutrons are analyzed. Splittings induced by thermal neutrons are studied in boron enriched emulsion. NTE exposed to mu-mesons at CERN.

There arises a problem calibration of ranges of heavy ions for ternary fission studies For this purpose Kr and Xe ions are implanted into emulsion at the JINR cyclotrons. Progress of analysis of NTE samples exposed to Am and Cf sources is presented.

Clustering features of light neutron-deficient nuclei in diffractive dissociation

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Nuclear track emulsion (NTE) is still retaining its exceptional position as a means for studying the structure of diffractive dissociation of relativistic nuclei owing to the completeness of observation of fragment ensembles and owing to its record spatial resolution. Separation of products of fragmentation and charge-exchange reactions of accelerated stable nuclei make it possible to create beams of radioactive nuclei. A unification of the above possibilities extends the investigation of the clustering phenomena in light radioactive proton-rich nuclei. Conclusions concerning clustering features are based on the probabilities for observing of dissociation channels and on measurements of angular distributions of relativistic fragments.

At the JINR Nuclotron exposures of NTE stacks of (NTE) are performed at energy above 1 A GeV to the beams of isotopes Be, B, B, C and N, including radioactive ones [1]. In general, the results confirm the hypothesis that the known features of light nuclei define the pattern of their relativistic dissociation. The probability distributions of the final configuration of fragments allow their contributions to the structure of the investigated nuclei to be evaluated. These distributions have an individual character for each of the presented nuclei appearing as their original “autograph”. The nuclei themselves are presented as various superpositions of light nuclei-cores, the lightest nuclei-clusters and nucleons. Recent data on pattern of diffractive dissociation of the nuclei 9C, 10C, 11C and 12N will be discussed in this context.

[1] P. I. Zarubin // Lect. Notes in Phys, Springer, **875**, 51 (2013); arXiv:1309.4881.

Influence of the nuclear dynamical deformation on production cross sections of superheavy nucleile

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The superheavy nuclear production mechanism can be described by fusion reactions with the dinuclear system concept, in which the deformations of the two nuclei are assumed to stay at their ground state with nucleons transferring between them. Actually the two nuclei have to deform due to very strong nuclear and Coulomb interactions between them. These deformations can be analytically described by a Fokker-Planck equation, and by combining them with a master equation that describes the nucleon transfer between nuclei the superheavy nuclear production cross sections can be investigated systematically. The calculated results are in good agreement with available data, and the evaporation residue cross sections for synthesizing the superheavy nuclei Z = 119 and 120 are predicted.

Hadronic "flow" in p–Pb collisions at the Large Hadron Collider?

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With Ultra-relativistic Quantum Molecular Dynamics (`UrQMD`) model we investigate the second and third Fourier flow-coefficients in p–Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV. The centrality dependence of 2-particle Q-Cumulant with various pseudorapidity gaps and 4-particle Q-Cumulants suggest that significant anisotropy azimuthal correlations could not be reproduced in p–Pb collisions with only hadronic interactions. Meanwhile a different shape of differential flow of second order Fourier flow-coefficient, $v_2(p_{\rm T})$, for charged particles is found in data and `UrQMD` model simulations. In addition, the characteristic mass ordering of $v_2(p_{\rm T})$ for identified particles is reproduced, in a non-flow dominant system simulated by `UrQMD` model. This could be explained by the usage of additive quark model, which assign different hadronic interactions to baryons and mesons. It implies that the mass ordering feature could but not necessarily be explained in terms of hydrodynamics.

All above results point out that azimuthal anisotropy measurements in p–Pb collisions can not be reproduced in the case of hadronic interactions only. The discrepancy between experiments and `UrQMD` simulations indicates that addition effects from the initial state and/or the existence of few drops of Quark-Gluon Plasma are required to reproduce the experimental measurements in p–Pb collisions at the LHC.