AGATA Collaboration Meeting 2021

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Legnaro National Laboratory

Book of Abstracts

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Annual AGATA Collaboration Meeting

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The Annual AGATA Collaboration Meeting of 2021 will be held at LNL in the date 10-11 November, after the Pre-PAC Meeting.

REPORTS on AGATA Experiments: SESSION 2 / 4

AGATA@GANIL(E676) (ONLINE): Lifetime measurements of excited states in neutron-rich C and O isotopes: a stringent test of the three body forces with the AGATA+PARIS+VAMOS setup

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Light neutron-rich nuclei, such as C and N isotopes, are a fertile ground for nuclear structure and nuclear astrophysics studies. Several nuclei in this region were populated in an experiment realised in GANIL, employing the deep-inelastic reaction ^{18}O (7.0 MeV/A) + ^{181}Ta and studied exploiting the state-of-the-art AGATA gamma-tracking array, coupled to the PARIS scintillation array and to the VAMOS++ recoil spectrometer. We will report on high-resolution gamma-spectroscopy investigations, focussing on the cases of ^{14}C and $^{18;19}$N , where new gamma transitions have been observed and state lifetimes have been measured, to benchmark ab initio ad large-scale Shell-Model theory predictions.

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AGATA@GANIL(E710): The lifetime of the 7.786 MeV state in 23Mg as a probe for classical novae models

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Simulations of novae explosive nucleosynthesis predict the production of the radionuclide ^{22}Na. Its half life of 2.6 yr makes it a very interesting astronomical observable by allowing space and time correlations with the astrophysical object. This radionuclide should bring constraints on nova

models. It may also help to explain abnormal ^{22}Ne abundance observed in presolar grains and in cosmic rays. Its gamma-ray line at 1.275 MeV has not been observed yet by the gamma-ray space observatories. Hence accurate yields of ^{22}Na are required. Within the novae thermal range, the main destruction reaction ^{22}Na(p,γ)^{23}Mg has been found dominated by a resonance at E_R = 0.213 MeV corresponding to the Ex = 7.786 MeV excited state in ^{23}Mg. However the measured strengths of this resonance are in disagreement [1, 2].

An experiment was performed at GANIL facility to measure the lifetime of the key state at Ex = 7.786 MeV. The principle of the experiment is similar to the one used in [3]. With a beam energy of 4.6 MeV/u, the reaction ^{3}He(^{24}Mg,α)^{23}Mg* populated the state of interest. This reaction was tagged with particle detectors (spectrometer VAMOS++, silicon detector SPIDER) and gamma tracking spectrometer AGATA. The state of interest decays either by gamma deexcitation or proton emission. The expected time resolution with AGATA high space and energy resolutions is 1 fs. Several Doppler based methods were used to analyse the lineshape of gamma peaks.

Preliminary results will be presented. Ejectiles, protons and α, were identified with SPIDER and VAMOS in order to reconstruct the excitation energies in ^{23}Mg. Doppler shifted gamma-ray spectra from ^{23}Mg states were improved by imposing coincidences with the α ejectile energies measured with VAMOS. It ensured to suppress feeding from higher states. Lifetimes in ^{23}Mg were measured with a new approach. Proton emitted from unbound levels in ^{23}Mg were also identified. With an higher precision on the lifetime of the Ex = 7.786 MeV state and the branching ratio measured in [4], a new value of ^{22}Na(p,γ)^{23}Mg resonance strength $\omega\gamma$ was obtained. The impact of the new thermonuclear ^{22}Na(p,γ)^{23}Mg rate on the predicted ^{22}Na production will be discussed.

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REPORTS on AGATA Experiments: SESSION 2 / 10

AGATA@GANIL (E706): Shape evolution in neutron-rich fission fragments in the mass A~100 region (1. Report)

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Nuclei around N=60, Z=40 show a rapid variation in the deformation of their ground state with a rather small change in the neutron number. This feature manifests a subtle interplay between different aspects of the forces in the nucleus and makes this region an ideal testing ground for various nuclear structure theories. As an example, it is established that the ground state of Zr isotopes vary from nearly spherical for N<60 to well deformed after N=60 [1–4]. However, theoretical models do not agree on the shape evolution of Zr beyond N=60 [5–10].
Lifetime measurements in neutron rich isotopes are an effective way to shed light on the shape evolution in this region of the Segrè chart. For this purpose, a successful experiment was performed in 2017 at GANIL by using the AGATA array coupled to the VAMOS spectrometer. The fast timing array FATIMA and the Orsay Universal Plunger system was also installed, allowing lifetime measurements in the range of 1 ps to 1 ns. The data set obtained from this experiment contains hundreds of isotopes and is producing many new interesting results.

With this contribution we will present the actual status of the analysis of this experiment, with a brief overview of what as been already done, what is ongoing and which are the future expectations. The aim of the present analysis is to obtain reliable lifetime results and error estimations through a comprehensive application of the Differential Decay Curve Method for the measurement of the lifetime both in single gamma and in coincidence gamma-gamma. We will show preliminary lifetime results obtained after the improvement of the velocity resolution of the emitting nuclei from the VAMOS data.

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AGATA Collaboration Meeting: SESSION 3 / 11

AGATA@GANIL(E731): Isospin Symmetry Breaking and Shape Coexistence in Mirror Nuclei 71Kr - 71Br

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The study of the nuclear deformation for nuclei between ^{40}Ca and ^{56}Ni, characterized by the $f_{7/2}$ proton and neutron shell, has historically played a fundamental role in developing the understanding of nuclear structure. In this mass region, the mirror pair ^{49}Cr and ^{49}Mn were well-studied through Mirror Energy Differences but the information on the evolution of quadruple collectivity is still limited for the ^{49}Mn because no lifetime for its excited states has been measured so far.

The experiment populated excited states in the mirror pair ^{49}Cr (2pn) and ^{49}Mn (p2n) nuclei using a fusion-evaporation reaction where a 115 MeV ^{36}Ar beam bombarded a CaO target. The detection of the gamma-rays was performed with AGATA (Advanced GAmma Tracking Array) spectrometer at GANIL in June 2018, during AGATA, NEDA + Neutron Wall, DIAMANT campaign.

In order to determine the lifetimes of the excited states, two different software packages have been used to perform Doppler Shift Attenuation Method analysis. Both methods have been tested in the ^{49}Cr with compatible results and are being applied to the ^{49}Mn to obtain the excited states lifetimes. The results for the ^{49}Cr lifetimes are compatible with literature and some preliminary results of the ^{49}Mn have been compared with shell model predictions.

REPORTS on AGATA Experiments: SESSION 2 / 12

AGATA@GANIL(E699) (ONLINE): Effects of Isospin Symmetry Breaking in the A=63 mirror nuclei

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This was the first experiment with NEDA and the full setup, and it suffered of some issues.
The (alpha+n) channel 63Ge has been searched carefully, so far without success. Many contaminating channels contribute to the background. In particular, we have found contaminant channels from the reaction induced by 40Ar, present in the beam producing residues with larger cross sections for neutron-evaporating channels. Oxygen contamination of the target is estimated to be 7% as well. Both contaminants, in the target and in the beam populate channel with higher cross section than 63Ge and therefore, so far it has not been possible to find its gamma lines. We remind that no gamma lines are known in this nucleus. In summary, the main goal of the experiment, 63Ge, is below the high background due to the contaminants in the beam and target.
However, some other channels are under analysis by students and researchers. In particular, we have found new transitions in the N=Z+1 65Ge and 64Ga.
The analysis of the angular distribution has been done for some channels. The analysis of the data from this experiment has been the subject of 3 bachelor thesis already finished and one in thesis is in progress. The lifetime of some states are being analysed in the framework of a PhD thesis.

REPORTS on AGATA Experiments: SESSION 2 / 13

AGATA@GANIL(E706) (ONLINE): Shape evolution in neutron-rich fission fragments in the mass A~100 region (2. Report)

Authors: Johannes Sørby Heines[1]; Victor Modamio[1]; Andreas Görgen[1]; Wolfram Korten[2]; Joa Ljungvall[3]; Giorgia Pasqualato[3]; Line Gaard Pedersen[1]

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The goal of Experiment E706 was to measure lifetimes of excited states in neutron-rich fission fragments in the mass A≈110 region. A beam of 238U was incident on a 9Be target, which was mounted in the OUPS plunger device together with a Mg degrader foil. The fission fragments were identified in mass and atomic number in the VAMOS++ spectrometer, while γ rays were detected with the AGATA and FATIMA arrays. The data analysis from the experiment, which is proceeding at IJClab Orsay, CEA Saclay, and the University of Oslo, has so far resulted in a PhD thesis at Université Paris-Saclay [1]. The general overview of the experiment and results on even-even nuclei will be presented in the contribution of G.Pasqualato.
In this report, we will present the optimization of the analysis procedure to improve the mass resolution and identification of ions in VAMOS. An overview of the wide range of nuclides for which lifetimes are being extracted will be given, with a focus on odd-even nuclei. We will furthermore present new ideas on how to utilize the information on the ion velocity from a spectrometer for determining lifetimes with the recoil distance technique.
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AGATA Collaboration Meeting: SESSION 4 / 14

AGATA@GANIL(E775s): Lifetime measurements of excited states in 20O populated by direct nucleon transfer

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Neutron-rich oxygen isotopes constitute a perfect playground for testing three-body forces.
For example, the neutron drip line is correctly predicted only when these forces are included in the calculation, as demonstrated by the work of Otsuka *et al.* [1].
In fact, standard shell model calculations including only two-body forces predict the drip line to be positioned at $N = 20$.
The inclusion of three-body forces has the effect of raising the $d_{3/2}$ orbital with the consequence of shifting the drip line from $N = 20$ to $N = 16$, as observed experimentally.
The importance of three-body forces is now established, however their contribution has yet to be quantified.

For this purpose, the ^{20}O represents an interesting case of study.
The non-yrast states 2^+_2 and 3^+_1 are based on a mixed $(d_{5/2})^3(s_{1/2})^1$ neutron configuration.
Hence, electromagnetic properties of the 2^+_2 and 3^+_1 states, such as the excitation energies, the branching ratios and the reduced transition probabilities, provide meaningful information on the position of the $d_{3/2}$ and $s_{1/2}$ orbitals, that are influenced by three-body forces.

An experiment aimed at measuring the lifetime of these states was performed at GANIL (France).
The ^{20}O was populated via a (d,p) reaction, using a post-accelerated radioactive beam of ^{19}O provided by the SPIRAL complex and a deuterated polyethylene target deposited on a gold degrader.
The beam-like and target-like partners were detected using the VAMOS spectrometer [2] and the MUGAST array [3], respectively.
The chosen reaction and the MUGAST and VAMOS detectors guaranteed a strong control on the population of the excited states and the capability of eliminating the effect of the feeders.
The γ rays emitted by the ^{20}O were detected by the AGATA array [4] at backward angles.
The lifetimes of the states were measured using the Doppler-Shift Attenuation method by comparing the lineshape of the experimental peaks to realistic Monte Carlo simulations.
In this contribution, the lifetime of the 2^+_2 and 3^+_1 states are presented.

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AGATA@GANIL(E708) (ONLINE): Evolution of collectivity around N=40: lifetime measurements in 73,75Ga

Authors: Tamara Milanović[None]; Igor Celikovic[1]

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The experiment E708 was performed in GANIL in 2016, aiming to investigate evolution of collectivity in odd mass Ga isotopes around N=40 and neighbouring nuclei. The lifetime measurements of the low-lying states in nuclei of interest would allow us to deduce the transition probabilities and extend our knowledge of the interplay between single-particle and collective degrees of freedom in this mass region.

Low-lying states in ^{73,75}Ga and neighbouring nuclei were populated
in deep-inelastic reaction in inverse kinematics with a ^{208}Pb beam at 6.63 MeV/A impinging on a 0.95 mg/cm^2 thick ^{76}Ge target.
The experiment was performed with the AGATA tracking array coupled to the VAMOS++ spectrometer which allowed us to detect the gamma-rays in coincidence with recoils emitted in the deep-inelastic reactions. Lifetime measurements were performed using the differential plunger device from University of Cologne and by applying the Recoil Distance Doppler Shift method.

The main physics goal, lifetime measurement of $5/2^-$ state in ^{73}Ga and ^{75}Ga using $\gamma\gamma$ coincidence data was not reached due to an order of magnitude lower beam intensity than proposed one. Nevertheless, lifetimes of $5/2^-$ state in ^{73}Ga and ^{75}Ga were determined by γ singles.
Measured lifetime and deduced transition probabilities of the $5/2^-{}_1$ state in ^{73}Ga support the argument of the M1 dominant nature of the $5/2^-_1 \rightarrow 1/2^-$ transition. Low-lying states in ^{70,72,74}Zn were analyzed by γ singles and the systematic discrepancy between B(E2;$4^+ \rightarrow 2^+$) values
measured by Coulomb excitation and plunger technique was investigated. Obtained results
are in agreement with those of previous plunger experiments. In addition, lifetimes of the low-lying states of germanium isotopes $^{75-79}$Ge were extracted using γ singles data.

AGATA Collaboration Meeting: SESSION 3 / 16

AGATA@GANIL(E730): Shell evolution of neutron-deficient Xe isotopes: Octupole and Quadrupole Correlations above 100Sn

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Shell evolution of neutron-deficient Xe isotopes:
Quadrupole and Octupole Collectivity above 100Sn
Status of the Analysis of the Experiment E730 performed with the AGATA-NEDA-DIAMANT-OUPS set-up

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The region that lies just above the Z=50 closed shell in the vicinity of 100Sn exhibits original collective behaviors. With the development of collectivity when adding protons in the g7/2 shell, shape coexisting structures, strong octupole correlations and strong neutron-proton couplings arise. With this experiment, we aim to address specific aspects of the collectivity development when approaching the N=Z line in light Xe isotopes by performing a precise lifetime measurement of excited states in 112Xe. The quadrupole degree of freedom, relevant to investigate the neutron-proton correlations [1], will be investigated through the lifetime of the 2+ and 4+. Additionally the lifetime of the 5- state, possibly together with information on branching ratios, might help address the question of the enhancement of the octupole correlation in the neighborhood of 112Ba[2].
The experiment was performed at the AGATA-NEDA-DIAMANT setup installed at the GANIL laboratory, with the CSNSM "OUPS" plunger device [3]. The 112Xe nuclei was populated in a compound nucleus reaction with a 58Ni beam impinging on a 58Ni 1 mg/cm2 target in the 2 proton 2 neutron evaporation channel. A 197Au degrader with a thickness of 5 mg/cm2 was installed in the plunger device to degrade the reaction products energy without stopping them, in order to maximize the sensibility. The detection on at least a neutron in NEDA+Neutron Wall [4] in coincidence with a gamma-ray in AGATA [5,6] was used as trigger while the information of DIAMANT was used off-line for identification and selection of the particle emitting channels. Nine Target-Degrader distances, ranging from 22 to 1500 micrometers, have been used to determine the lifetimes of interest. The calibration, alignment, definition of the neutrons and light charged particle conditions and final sorting of the data was completed before the end of 2019.
In this contribution, we will report on the on the status of the analysis and the preliminary findings.

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REPORTS on AGATA Experiments / 17

AGATA@GSI (S433): Collectivity in 52Fe revisited with relativistic RIB techniques

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In this work, we studied the structure of the pf-shell N=Z nucleus ^{52}Fe with relativistic radioactive ion beam techniques to reveal the collectivity in this region. ^{52}Fe presents an interesting case in which we see the onset of a collective structure that is more common nuclear property in heavier nuclei. We deduced the reduced transition probability of the $0^+_{gs} \rightarrow 2^+_1$ and $0^+_{gs} \rightarrow 2^+_2$ transitions by measuring the relativistic Coulomb excitation cross sections using state-of-the-art detectors AGATA at GSI [1, 2]. Our results deviate from two other previously reported BE(2) values [3, 4]. The reduced transition probability of a third state, observed in this study, will also be exhaustively discussed. The results will be interpreted in the framework of the LSSM.

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AGATA Collaboration Meeting: SESSION 4 / 18

AGATA@GANIL(E768S) (ONLINE): New measurement of oxygen-15 alpha capture for neutron stars in binary systems

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We present new experimental results for a measurement utilising the combination of AGATA, MUGAST, and VAMOS for a determination of the astrophysical ^{15}O alpha capture reaction rate [1]. This reaction is a key breakout route from the Hot CNO cycle leading to explosive nucleosynthesis via the rp-process on the surface of neutron stars in binary systems. Determining an accurate cross section for the relevant states is critical for a better understanding of the X-ray burst energy production and light-curves [2], and may even initiate rp-process nucleosynthesis in other novel binary stellar systems involving neutron stars, such as the common envelope scenario [3].

An indirect ^{7}Li(^{15}O,t)^{19}Ne alpha transfer reaction measurement in inverse kinematics is presented and the direct link to the astrophysical reaction rate is demonstrated. In this reaction we populate the relevant states for temperatures up to 1GK. In the experiment we take advantage of the post-accelerated ^{15}O Radioactive Ion Beam provided at GANIL and the state-of-the art detection system VAMOS [4] + AGATA [5] + MUGAST [6] coupled together for the first time [7]. This allows us an unrivalled selectivity for detecting coincidences of all final state particles in this reaction.

We will present the experimental set-up and analysis, results for the strongest populated resonances in ^{19}Ne as well as a new result with reduced errors for the alpha width of the critical 4.033MeV excited state. We will finally relate this to the astrophysical ^{15}O(α,γ)^{19}Ne reaction rate.

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AGATA Collaboration Meeting: SESSION 3 / 19

AGATA@GANIL(E703): Studies of excited states in 102,103Sn to deduce two-body neutron interactions, single-particle energies and N=Z=50 core excitations

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The E703 experiment was performed at GANIL in April–May 2018, with the setup of AGATA-NEDA-DIAMANT. This measurement aimed at the observation of gamma rays emitted from excited states of the nuclei 102Sn and 103Sn, from which two-body neutron interactions, single-particle energies and N=Z=50 core excitations could be inferred. The data analysis is pursued in Warsaw, Stockholm and Uppsala.
In depth optimisation of conditions of AGATA-NEDA-DIAMANT event building, NEDA neutron-gamma discrimination, NEDA two-neutron discrimination, DIAMANT charged particle identification and of the timing of all the components of the system were done. Stability corrections and calibrations were also completed. Several replays of the entire data set were run, with various event-building time conditions, and multiplicity conditions of the three used detector systems. This was necessary in order to enable study of both delayed and prompt gamma-ray radiation, emitted from states below and above the 6+ isomeric state in102Sn (T½ = 400 ns).
These procedures resulted in a very clean identification of events in which the two known gamma rays of 102Sn, namely 497 and 1472 keV, were registered. The statistics of the identified events is very low, though. In the gamma-gamma coincidence spectrum gated on the 1472 keV line, obtained with the condition that 2 neutrons and 1 alpha particle are registered, as well as that the two gamma rays are registered within a 50 ns window, but could be delayed up to 2 μs with respect to the prompt RF signal, there are 15 counts in the 497 keV peak. The spectrum contains virtually no background. The analysis of the data is continued, with the aim to identify new gamma-ray transitions emitted from excited states of 102Sn.

AGATA Collaboration Meeting: SESSION 4 / 20

AGATA@GANIL(E744) (ONLINE): Narrow resonances in the continuum of 15F

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Two recent measurements performed at GANIL studied the unbound nucleus ^{15}F using a SPIRAL 1 radioactive ^{14}O beam impinging on the hydrogen nuclei from a thick (100 μm) polyethylene (CH_2) target. The first experiment was performed using the MUST2 light-particle detector array at LISE. The second experiment was part of the campaign using the new MUGAST light particle detector array, the VAMOS spectrometer and the AGATA γ-ray detector array.
The unbound nucleus ^{15}F was shown to be of high interest due to the existence of quasi-bound states located well above the Coulomb barrier. Recently a $1/2^-$ narrow resonance located near the two-proton emission threshold (S_{2p}) has been observed and other narrow states of higher energy, a $5/2^-$ and a $3/2^-$ were predicted $\sim$ 1 MeV above S_{2p}. The previously observed $1/2^-$ state might be a good candidate to study γ emission in an unbound nucleus as the decay between the $1/2^-$ to the $1/2^+$ ground state would be an E1 transition.

This contribution will present our final results on the measurement of the one and two proton emission as well as the current status of the analysis of the gamma decay in an unbound nucleus.

REPORTS on AGATA Experiments: SESSION 2 / 21

AGATA@GANIL(E693) (ONLINE): Exploration of alpha-cluster structures in heavy nuclei: The unique case of 212Po (208Pb + alpha)

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Some years ago, unnatural-parity doublet states in 212Po with spins of 4-, 6-, and 8-, which were observed to decay via strong E1 transitions to the yrast band in an experiment performed with the EUROBALL spectrometer, were interpreted as being of alpha-cluster structure. Subsequent theoretical work seemed to support this interpretation. The aim of experiment E693 was to study the alpha-cluster properties of the nucleus 212Po in more detail. Although the experiment was seriously hampered by target problems, its analysis still led to very important conclusions. The new experimental information, together with a detailled comparison with shell-model calculations, suggests that the states of interest have positive rather than negative parity and decay via strong M1 transitions.

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AGATA@GANIL(E708): Evidence of partial seniority conservation in the proton g9/2 shell for the N=50 isotones

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In order to shed light on the open question of the seniority conservation in the proton g9/2 orbital in the N=50 isotones [1,2], reduced transition probabilities in 90Zr, 92Mo and 94Ru nuclei, have been determined experimentally for the first time via lifetime measurements at the GANIL laboratory. The unconventional use of multi-nucleon transfer reaction [3] with a differential plunger device [4] allowed to measure lifetimes of the yrast low-spin states despite the presence of isomers in the proton-rich isotones. The required sensitivity to the lifetimes could only be achieved due to the excellent performance of the AGATA+VAMOS++ detection system [5,6].

The B(E2;4+->2+) and B(E2;2+->0+) yrast transitions in 92Mo and 94Ru and for the B(E2;4+->2+) and B(E2;6+->4+) yrast transitions in 90Zr determined in this experiment will be shown. In this contribution these results will be interpreted on the basis of realistic shell-model calculations [7] in the f5/2, p3/2, p1/2, g9/2 valence space, where it emerges that seniority is conserved in the first g9/2 orbital.

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The EXOTIC beam line at LNL

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AGATA@GANIL(E786s): Protons in the sd shells along the N=28 chain: only spectators ?

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The evolution of the nuclear shell closure along N=28 has gathered much interest due to the observed discrepancies between the well established shell model with SDPF-U interaction and measurements of
the half-magic 46Ar isotope.

In particular, while remarkable agreement was observed between theoretical and experimental values
of Sn, transition probabilities measured with intermediate Coulomb excitation diverge by a factor of two
from their predicted values[1, 2]. The reason behind this mismatch has been pinned down to the proton
transition matrix elements[2] and hints at an incorrect description of the sd proton space below Z=20 [3].
The experiment we proposed aimed at shedding some light on this peculiar problem by directly probing the proton component of the wavefunction via a proton-pickup direct reaction: 46Ar(3He, d)47K
at an energy of 350 MeV.
The experiment, performed at the Spiral 1 facility in GANIL with a post-accelerated radioactive 46Ar beam impinging on a high-density cryogenic 3He target, will assess the amount of d3/2 state relative to
the s1/2 relying on a state-of-the-art experimental setup for a precise reconstruction of the kinematics of
the reaction.
The heavy reaction fragment was identi ed by the high acceptance magnetic spectrometer, VAMOS, while the high-granularity silicon DSSSD detector, MUGAST, allowed the measurement of the angular
distribution of the light ejectile while also performing particle identi cation. The AGATA[5] gamma-ray
tracking germanium array measured the gamma rays produced by the decay of the 47K excited states.
Experimental results will be compared with theoretical models to infer information on the proton wavefunction of 46Ar.
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AGATA@LNL: Future Campaign

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The EXOTIC beam line at LNL

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