Young GAMMAs Meeting

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Osservatorio astrofisico di Asiago

Raccolta degli abstract

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Double-γ measurement and its implications on $0\nu\beta\beta$ decay

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Neutrinoless double-beta decay is a second-order decay process of atomic nuclei suggested by theories beyond the Standard Model. This decay would constitute the first observation of lepton-number conservation symmetry violation in the laboratory, showing that neutrinos are their own antiparticles. The neutrinoless double-beta decay rate depends on a Nuclear Matrix Element (NME), which is a key parameter to design experiments and fully exploit their results. Unfortunately, for each of the neutrinoless double-beta candidate nuclides the corresponding NME presents large uncertainties. A recent publication showed a very good correlation between the matrix elements of neutrinoless double-beta and double-gamma decay from the Double Isobaric Analog State (DIAS) of the initial double-beta state, i.e. the state carrying the same wavefunction except for a rotation in the isospin space, into the final double-beta state. Therefore, we could attack the lack of experimental data on the NME values by studying the two-photon decay process. The only neutrinoless double-beta candidate for which the DIAS is known is the ^{48}Ca isotope, which therefore constitutes the ideal study case to start with. Given the very small double-gamma decay rate expected for this nucleus, it is essential to characterize the contributions of all the competing processes and determine the optimal setup and data processing methods to maximise the double-gamma detection efficiency. For this reason a dedicated custom simulation program based on the GEANT4 framework was developed, in order to simulate the experimental setup and its response to the radiation emitted in the ^{48}Ti nuclear de-excitation. After validating the setup and the simulation outputs, different analysis methods were implemented to suppress the decay processes competing with the double-gamma decay. Promising results concerning both the identification of the double-gamma events and the associated NME extraction were obtained, supporting the feasibility of an experiment aimed at measuring this exotic process in ^{48}Ti. When performed, this measurement will provide the first experimental constraints on the ^{48}Ca neutrinoless double-beta decay NME.

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Searching for the microscopic origin of shape coexistence in Ca isotopes

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Nuclear shape coexistence plays a crucial role in understanding the microscopic origin of nuclear deformation.
The Ca isotopic chain between ^{40}Ca and ^{48}Ca is an optimal test area that can provide key information on shape coexistence when moving from the valley of stability towards the neutron-rich region of the Segrè chart.
This work aims to perform complete low-spin spectroscopy of ^{42,43,44,45}Ca isotopes, complementary to the already existing data of ^{41,47,49}Ca, and to look for evidence of shape coexistence in the A~ 40 region.
As a first step in this direction, we focused on ^{42}Ca, where evidence for a 0^+ excitation associated with a superdeformed shape has been obtained in a Coulomb excitation experiment.
The ^{42}Ca nucleus of interest was populated with a (n_{th}, γ) reaction on a ^{41}Ca radioactive target.
The γ cascades emitted from the 11.480 MeV capture state were detected using the 32 HPGe crystals array FIPPS, at ILL (Grenoble).

The result of this work is a complex level scheme that will be presented together with preliminary angular correlation studies made to establish spin and parities of several excited states of ^{42}Ca.

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Search for shape coexistence in Sn isotopes around A=110

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In this contribution, we present our investigation of the shape coexistence phenomenon in Sn isotopes around A=110, by means of γ-ray spectroscopy and lifetime measurements of low-spin states. Recent observation of axially deformed 0^+ states in ^{64,66}Ni isotopes suggested the possibility of having similar excitations in the stable Sn isotopes, across the $Z = 50$ shell gap, due to analogies in the orbital configuration. Such hypothesis is corroborated by Monte Carlo Shell Model (MCSM) calculations, whose potential energy surfaces of $^{110-118}$Sn exhibit a well-separated prolate secondary minimum, as in the Ni case.\\
Experimentally, several excited 0^+ states have been observed in even-even $^{110-118}$Sn, mainly via particle spectroscopy, however limited information on their lifetimes is available. To address this issue, a series of complementary experiments was carried out by our collaboration between LNL and IFIN-HH, employing the ROSPHERE-SORCERER and the AGATA-PRISMA setup, respectively. In particular, ^{110,112,114}Sn were populated by low-energy multi-nucleon transfer reactions and the plunger method was applied to determine the lifetimes of excited states. Preliminary results will be compared with MCSM calculations, giving an insight into the microscopic mechanism leading to the onset of deformation in this region.

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Lifetime measurements in the N=126 region with the reversed plunger configuration

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A novel technique has been developed to measure lifetimes of heavy neutron-rich nuclei, namely 'the reversed plunger'. In heavy neutron-rich nuclei, information on the lifetimes of low-lying excited states is scarce since these nuclei are difficult to populate. Among different reaction mechanisms, multi-nucleon transfer reactions have shown to be the perfect tool to explore such regions. Therefore, profiting from the kinematics of such reactions and the plunger device in the reversed configuration, lifetimes of excited nuclear states of the order of picoseconds can be measured.
This technique was employed for the first time at Laboratori Nazionali di Legnaro to measure lifetimes of low-lying excited states of nuclei with a mass of around 190, where shape transitions from prolate to oblate are expected to occur along different isotopic chains while approaching the N=126 shell closure.
A beam of ^{136}Xe with the energy of 1134~MeV passed through a degrader foil of ^{93}Nb with a thickness of 3.2~mg/cm^2 and impinged into a ^{198}Pt target 1.4~mg/cm^2 thick. Beam-like fragments entered the PRISMA spectrometer where they were identified in mass, atomic number, and velocity, while the target-like fragments (the heavy nuclei of interest) traveled towards the degrader foil where they were stopped. Gamma rays were measured with the AGATA tracking array composed of 33 segmented HPGe detectors. Among the nuclei populated in this experiment is ^{198}Pt, for which the lifetimes of the low-lying excited states are known, and can be used as a benchmark to validate the

use of the proposed technique.
This work reports the lifetimes of the 2_1^+, 2_2^+ and the 4_1^+ states of ^{198}Pt measured with the reversed plunger configuration, employing the standard analysis procedures: the Decay Curve Method and the Differential Decay Curve Method. The agreement of our results with the literature data demonstrates the capability of this technique to further investigate the nuclear structure of heavy neutron-rich nuclei.

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Octupole Collectivity in ^{96}Zr from Low-Energy Coulomb Excitation with the AGATA+SPIDER Setup

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An experiment was performed to investigate the octupole collectivity in the ^{96}Zr isotope, for which the structure of the first 3^- state has been widely debated in the literature. Previous measurements suggested that the γ-ray transition probability for the first 3^- state is one of the largest across the nuclear chart. This observation has never been reproduced by any theoretical calculations, and it is puzzling as it does not correspond to a similar increase in the neighbour isotopic chains. A recent study, instead, provides a significantly reduced γ-ray transition probability for the $3_1^- \rightarrow 0_1^+$ transition, which is in better agreement with state-of-the-art shell-model calculations. Nevertheless, up to now the experimental values were obtained only via indirect methods. We performed a dedicated Coulomb-excitation study of the nucleus ^{96}Zr utilising the γ-ray tracking spectrometer AGATA coupled with the heavy-ion detector array SPIDER at INFN-LNL. This investigation is extremely timely in order to provide directly the $3_1^- \rightarrow 0_1^+$ γ-ray transition probability for the first time. In this talk, we will present the preliminary results on the decay of this state to the ground state. The obtained B(E3) value seems to confirm how this quantity is not as large as previously thought, supporting the idea that it does not represent an outstanding value in the nuclide chart.

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Search for a Josephson-like effect in the ^{116}Sn+^{60}Ni system

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The pairing interaction, responsible for the two-nucleon correlation, plays a fundamental role in defining the low-energy spectra of atomic nuclei and the properties of their ground state. The effect of pairing correlations in the reaction dynamics can be explored by using heavy-ion reactions, in particular those involving a transfer of few nucleons. In this context, an interesting analogy between the nuclear pairing and the Cooper pairing in superconductors can be investigated through heavy-ion collisions, focusing on nucleon-pair transfer and searching for a possible effect, predicted by a BCS-like theory applied to nuclei: the Josephson Effect. The idea was already suggested in the '70s, but only recently more quantitative calculations, assisted by promising experimental results, revived the interest on the subject and ignited a more systematic research. The transfer of neutron Cooper pairs was therefore studied through the interaction between two superfluid nuclei, ^{116}Sn and ^{60}Ni, using the Advances Gamma-Ray Tracking Spectrometer AGATA and the large-acceptance magnetic spectrometer PRISMA at Legnaro National Laboratories, INFN.

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Electron spectroscopy @LNL: Present and future perspectives

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Electron spectroscopy is a powerful tool in the investigation of fundamental properties of the atomic nucleus, essential in the study of nuclear structure, where empirical nuclear models provide a framework to understand many nuclear phenomena. The study of electric monopole transitions between nuclear states having the same spin and parity can make an important contribution to clarifying the configuration of the nuclear states. Electric monopole (E0) transitions are determined by a change in the radial distribution of the electric charge inside the nucleus, and high E0 transition strengths are expected whenever configurations with different mean-square charge radii mix. In this regard, an enhancement of the monopole strength in transitions between $\Delta J = 0$ states may be considered as a "signature"for shape coexistence.
Shape coexistence, according to Poves [J. Phys. G: Nucl. Part. Phys. 43, 020401 (2016)], is "a very peculiar nuclear phenomenon consisting in the presence in the same nuclei, at low excitation energy, and within a very narrow energy range, of two or more states (or bands of states) which: (a) have well defined and distinct properties, and, (b) can be interpreted in terms of different intrinsic shapes." . The distinctive character of shape coexistence lies in the interplay between two opposing trends: shell and subshell closures have a stabilizing effect leading to sphericity while residual interactions between protons and neutrons outside closed shells drive the nucleus to deformation.
The measurement of the monopole strength is complicated by the fact that E0 transitions can proceed solely via internal conversion or pair production (if the transition energy is larger than $2m_0c^2$). Simultaneous emission of two photons is a higher-order process (relative probability $\sim 10^{-3} : 10^{-4}$) and is usually neglected.
The measurement of conversion electrons is typically achieved using silicon detectors, drifted with lithium (Si(Li)), coupled with a magnetic transport system. The latter allows a high efficiency for electron collection on the detector together with the powerful rejection of background γ-rays.
As an example, the features of SLICES (Spes Low energy Internal Conversion Electron Spectrometer), installed at Legnaro National Laboratories, will be presented in this seminar. SLICES consists of a large area Si(Li) detector used in conjunction with a magnetic transport and filter system. The large unconventional size of the lens and detector, compared to a traditional mini-orange arrangement, will grant a large acceptance in both electron energy and emission angle, ensuring the high efficiency of the apparatus.

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Towards the complete realization of a coaxial and segmented detector for gamma spectroscopy experiments

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The higher counting-rate and radiation hardness required by modern gamma spectroscopy experiments highlight the need for a new generation of High-Purity Germanium (HPGe) detectors based on electrons-collecting electrodes. To achieve this goal, a new doping technology, the Pulsed Laser Melting (PLM), has been developed. This technique is being applied to coaxial detectors in the framework of the N3G (Next Generation Germanium Gamma detectors) project which is also aimed at developing a case able to contain and protect the detector and at designing its contact structures and front-end electronics.
Once the doping is realized on the detector surface, a thin (less than 100 nm) layer of gold is deposited by sputtering. This layer is necessary to segment the realized junction, since it is resistant

to the acid etching of germanium. Then the photolithography segmentation process is performed. A positive photoresist is deposited on top of the gold layer and an acetate mask is used to protect the electrodes from the UV irradiation. After the irradiated photoresist is removed, a gold etching is done to remove the gold between the segments. Finally the detector is chemically etched to remove the junction diffusion on the gap and quenched with a methanol passivation.
The electrical connection of the electrodes is made possible by a flower-shaped PCB (Printed Circuit Board). This solution doesn't scratch the brittle surface of the detector and works properly at cryogenic temperatures. Furthermore it decreases the detector leakage current with respect to the connection-systems previously used. This flexible PCB is than connected through a rigid one to the read-out electronic chain.
The detector and the electrical connections are housed into a vacuum-tight canister, made by an aluminum cylindrical case closed by a stainless steel flange. This system contains and protects the detector and makes it possible to operate in high-vacuum condition. Moreover the whole mechanics is compatible with the cryostats available from LNL (Laboratori Nazionali di Legnaro).
The detector, its mechanics and its electronic connections have been assembled and tested. Of the available segments, the current-voltage curves were extracted together with the resistance between adjacent electrodes themselves. Segments resulted well isolated from each other (resistances on the order of $10^{12} - 10^{13}$ Ω) and the flexible PCB applied didn't scratch their surface . Moreover, part of the electrodes showed a leakage current on the order of $10^{-12} - 10^{-11}$ A, several orders of magnitude lower than the one measured with typical contact structures.

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Beta decay studies in the HISPEC/DESPEC FAIR Phase-0 campaign at GSI

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The work presented is focused on experimental results from two experiments performed using the FRS+DESPEC setup at GSI-FAIR in spring 2021 The two experiments aimed at studying two different regions of the nuclear chart, extending from the heavy n-rich side around A∼225 towards the p-rich ^{100}Sn region.
The main results from the analysis of the heavy n-rich region is the first measurement of β-decay half-lives. A comparison with theoretical models highlights the role of first-forbidden transition and are fundamental inputs for the description of the r-process nucleosynthesis.
The β-delayed decay pattern was studied in ^{100,101,102}Cd. New levels were added to the level scheme of ^{101}Cd, and compared to large-scale shell model calculations. In the same experiment, lifetimes of low-lying excited states below the 8^+ seniority isomer in the neutron-deficient ^{98,100}Cd isotopes were performed and the calculated B(E2) values were compared with state-of-the-art shell model calculations.

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Gamma-ray spectroscopy following beta-decay: present at TRIUMF and future at SPES

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In this talk, I will present the GAMMA activities at TRIUMF with the GRIFFIN gamma-ray spectrometer. I will describe the facility and the experimental setup, focusing on ongoing and future physics campaigns in different regions of the nuclide chart. Finally, I will introduce future activities at the SPES's beta-decay station.

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Lifetime measurements for the study of intruder states towards the island of inversion along the N = 20 shell closure

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Lifetime measurements are commonly used to unravel the nature and properties of nuclear states, as they are closely related to transition probabilities, which provide information on the nuclear wave functions. The aim of the experiment here presented was to study the interplay of spherical (0 $\hbar\omega$) and intruder (2 $\hbar\omega$) configurations in the low-lying states of isotopes on the edge of the N=20 island of inversion. In particular, the goal was to determine the lifetime of the first two 2+ states of Si and the first 5/2+ state of ^{35}P using the **Doppler Shift Attenuation Method**. The experiment was conducted at the LNL facility in November 2022, employing the PRISMA magnetic spectrometer and the AGATA array.

This presentation provides an overview of the first-step analysis of the experiment, which involved the AGATA and PRISMA data processing and the optimization of the AGATA GEANT4 simulation, which was adapted to mimic the experimental conditions.

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Spectroscopy studies in the A = 18 - 26 Ne-F region using the AGATA-PRISMA spectrometer

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I present recent AGATA-PRISMA results obtained at Laboratori Nazionali di Legnaro to study the transition into the N = 20 Island of Inversion by multi-nucleon transfer reactions using a 22Ne beam and a 238U target. The experiment aims at exploring the boundaries of the Island of Inversion, following the evolution of negative parity states from the fp shell, locate excited intruder configurations and tracking the development of quadrupole and octupole collectivity toward N = 20. This study is primarily focused on the spectroscopy of Ne and F isotopes with neutron number N = 10 –16 to benchamrk state-of-the-art nuclear structure theories. The experimental setup, comprising the AGATA γ array coupled to the PRISMA magnetic spectrometer, allowed us to detect and identify the ions of interest and measure, in coincidence, γ rays from excited states. AGATA-PRISMA calibrations and preliminary results will be discussed.

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GEANT4 Simulation for nuclear and interdisciplinary physics

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GEANT4 is a powerful tool to characterize the capabilities of an experimental setup. In this talk, I will present the preliminary results of GEANT4 simulations for two different apparatuses: the Beta decay station, soon to be installed at the INFN laboratories of Legnaro and the Begam project for the study of radiopharmaceuticals.

The beta decay station focuses on studying exotic ions. Investigating the β decay of these isotopes provides crucial insights into nuclear structure, astrophysical processes, fundamental interactions, and the limits of our current understanding of the universe. To achieve accurate simulations of the beta decay station, several considerations must be addressed. GEANT4's built-in radioactive decay option does not account for β decays with delayed neutron emission, the database may not be fully up-to-date for exotic isotopes, and furthermore the proper timing of the measurements is essential.

To address these issues, four Wolfram Mathematica software have been developed to be used in advance of the simulation. These software provide comprehensive information for the simulation by: listing all the decay processes for a given ion, optimizing the measurement and implantation time windows and calculating conversion coefficients to update the GEANT4 database. The simulation and the Wolfram Mathematica codes have been validated using a beam of ^{148}Cs isotopes, obtaining satisfactory results. We expect both the software and the simulation to became a useful tool that can help to better understand the measurements that will be performed in the future, once the beta decay station will be fully operational.

The second part of the talk will focus on the Begam project, which involves developing a new apparatus to detect β^- contaminants in radiopharmaceuticals through coincidence (or anti-coincidence) measurements of β particles and γ rays.

At this stage we are implementing GEANT4 simulations to test the realistic configuration of the proposed device. This device features a hollow cylindrical plastic scintillator to hold the radioactive sample, mounted on top of a solid CsI cylinder. The two layers are surrounded by CsI(Tl) sectors, ranging from four to eight, arranged to form a cylinder. The dimensions and number of the scintillators will be determined based on the simulation results.

The first test will be performed on an eluate of ^{99m}Tc, as its production through radionuclide generators may result in the presence of the β decaying radioisotope ^{99}Mo. In fact, the acquisition of the γ spectrum in coincidence with respect to the β signals, will allow to select the γ radiations coming from the ^{99}Tc levels populated by the parent ^{99}Mo nucleus, rejecting the γ rays coming from the IT decay of the 143 keV isomeric level of ^{99m}Tc. This will make it easier to accurately estimate the percentage of ^{99}Mo present in the solution.
In a further future BEGAM will be used to analyze the purity of the radionuclides produced at medical cyclotrons like for example the ^{68}Ga.

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Study of the 85gKr(d,pγ) reaction for astrophysics at ANL

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About 50% of the elements heavier than iron are produced in the so-called s-process, where the lifetime for neutron capture of the nuclei involved is typically longer than their β-decay lifetimes.

In the modeling of the s-process, great uncertainty derives from the competition between neutron capture and β-decay, in particular in some isotopes called "branching points". ^{85}Kr is an important branching point of the s-process, that influences both the ^{86}Kr/^{82}Kr ratio in presolar grains and the abundances of heavy Sr isotopes that are produced also by r-process. A better understanding of this branching point can be achieved only if the neutron capture cross section on ^{85}Kr is sufficiently well constrained, but a direct measurement of this cross section is extremely complicated due to the radioactivity of the sample.
The (d,pγ) reaction has been demonstrated to be a reliable indirect probe of the (n,γ)-reaction cross section, and ^{85}Kr can be accelerated as a pure beam. For this reason, the ^{85}Kr(d,pγ)^{86}Kr reaction has been carried out at 10 MeV/u in inverse kinematics at Argonne's ATLAS facility using the HELIOS spectrometer and the Apollo array. Excited state at energies from around 2-14 MeV in ^{86}Kr were populated, where S_n=9.86 MeV, with a Q-value resolution of about 150 keV. The $2^+ \rightarrow 0^+$ and $4^+ \rightarrow 2^+$ γ-rays are clearly observed, from which the γ-ray emission probabilities as a function of excitation energy [$P_p(E_{ex})$] can be determined. P_p shows the characteristic behaviour with a constant value below S_n and a decrease at higher excitation energies. These data are used to extract the cross sections for ^{85}Kr(n,γ) reaction, complementing recent direct, high-precision measurements on the stable Kr isotopes. The technique has significant potential for future indirect (n,γ)-reaction studies.

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Ancillaries at LNL

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A brief presentation about available ancillary detectors at LNL, use cases, optimization processes and future plans.

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DSAM of ^{56}Ni

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A very brief report on the progress of the analysis of the DSAM experiment studying deformation in ^{56}Ni using AGATA-OSCAR setup at LNL

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Characterization of new scintillator detectors for high-energy gamma-ray measurements

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Large-volume scintillator detectors are used in nuclear physics experiments with high-energy gamma rays. In this paper, I'm presenting the R&D work performed in Milano on scintillators and their employment in collective motion experiments. There are two main activities in Milan: the first one regards the CLYC scintillators, focused on their fast neutron efficiency, whereas the second is on the possibility of replacing photomultipliers tubes with silicon photomultipliers to enhance scintillator performances in a magnetic field and providing position sensitivity. In nuclear physics experiments where the aim is the study of the collective motion in nuclei, scintillators are the best candidates. This paper presents a few physics cases, such as the isospin mixing and the pygmy dipole resonance, and the preliminary results of two experiments performed in Krakow. The first aims to measure the pygmy dipole resonance in nickel isotopes, and the second to detect the gamma-ray decay of the giant quadrupole resonance in ^{120}Sn.

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Lifetimes in ^{37}S

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The disappearance of the $N = 20$ shell closure in the so-called "island of inversion"around ^{32}Mg is one of the most striking examples of the strength of nucleon-nucleon correlations. In this region, the quadrupole-deformed intruder configuration (based on a multi-particle multi-hole configuration) becomes the ground state, subverting the expected shell ordering predicted by a harmonic oscillator plus spin-orbit term. The odd $N = 21$ isotonic chain provides the possibility to study the single-particle and intruder states as a function of decreasing Z. Available spectroscopic evidence points out the appearance of strong branching ratios among the single-particle and collective intruder configurations in ^{37}S, suggesting that they mix significantly, contrary to the notion of ^{37}S being well out the island of inversion. However, a precise quantification of this phenomenon in terms of transition strength is still lacking. The first excited state ($3/2^-$ state at 646 keV) is the only one with a measured lifetime, but no transition probability has been firmly determined for the intruder states, in particular those decaying to the a priori spherical single-particle states. A combined DSAM+RDDS measurement has been performed to measure such transition probabilities, in particular for the 2p-1h $3/2^+$ state at 1397 keV and the 3p-2h $7/2^-$ at 2023 keV, exploiting the performance of the AGATA spectrometer in terms of energy and angular resolutions. The 37S nucleus has been produced via the ^{36}S(d,p) reaction in inverse kinematics, detecting the recoiling protons in the silicon array SPIDER to obtain an accurate reconstruction of the excitation energy of ^{37}S. The short lifetimes measured point to large M1 and/or E2 strengths connecting the intruder and spherical states. This would imply a significant mixing between the configurations, arising questions about the determination of the neutron p3/2-p1/2 single-particle strength distribution in ^{37}S.

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Update on the coupling between the In-Flight Radioactive Ion Beam Facility EXOTIC and AGATA

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During the past year, the EXOTIC facility underwent several upgrades, including the installation of newly developed Micro-Channel Plates (MCPs). This enables the event-by-event identification of the radioactive ion beam by the two detectors positioned upstream of the AGATA target chamber. The present setup facilitates the tracking of incoming particles, thereby enabling the separation of the desired secondary beam from contaminants.

In October 2023, a 2-day run successfully tested the re-operation of the facility, encompassing primary beam focusing and monitoring, performance evaluation of the new software for remote control of magnetic fields and slits, as well as secondary beam selectivity and purification.

Subsequently, off-line testing of the first MCP with α sources confirmed the expected functionality of the detector. During the development of the second MCP, successful off-line testing of the tracking system for the coupled system MCP+DSSSD (32 strips $\times$32 strips) was also performed.

We will report on the preliminary results obtained from the offline tests of the two micro-channel plates, including estimated efficiencies, time-of-flight, and position resolutions. Additionally, the capabilities of the newly constructed position-tracking system will be discussed.

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Spectroscopy and fission studies in inverse kinematics: ^{208}Pb + ^{9}Be with AGATA and PRISMA

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In December 2022, an experiment was performed at INFN-LNL with a ^{208}Pb beam at 1300 MeV impinging on a ^{9}Be target, using the inverse kinematics fusion-fission reaction for both nuclear structure and reactions studies. The experiment was performed using the AGATA γ-ray tracking array coupled to the magnetic spectrometer PRISMA.
This setup allowed one to measure the γ rays from the de-excitation of the fission fragments and to study the dynamics of the fission of the compound nucleus, ^{217}Rn.
One of the interesting nuclear structure issues that can be tackled in the neutron-rich region reached through the fission of this system is the evolution of the shell gap at $N = 50$.
The observation of the reduction of the $N = 50$ shell gap is a phenomenon that motivated different measurements in the $N = 50$ isotones towards ^{78}Ni.
In particular, estimates starting from mass measurements show a decrease of the $N = 50$ gap size from $Z = 40$ until ^{82}Ge, while for ^{80}Zn a re-increase is observed. A second method to estimate the gap size is with the energy of medium-spin states in $N = 50$ even-even isotones.
The fusion-fission reaction mechanism is an effective production method for spectroscopy of these levels because it can populate states at higher spins than transfer reactions, up to 6-8 units of angular momentum.
Preliminary results on γ-ray spectroscopy of $N = 40 - 50$ isotopes in the region around $Z = 32$ will be shown.
In parallel to the γ-ray spectroscopy of the energy levels of the fission products, the measurement of the fragments with the large acceptance spectrometer PRISMA gives access to key quantities for the description of the fission dynamics of the ^{217}Rn compound nucleus. The (A, Z) identification and the reconstruction of the fragment velocities in the center of mass of the fissioning system allow the extraction of relevant observables, such as the total kinetic energy (TKE), the neutron excess N/Z and the neutron evaporation as a function of the nuclear charge.
For the examined system of ^{217}Rn, symmetric fission is expected and therefore structure effects on the yield distribution should be smaller, but the neutron-rich part of this region was never tested

experimentally and observables which are sensitive to the influence of nuclear structure in fission, such as N/Z, still have to be studied.
The goal in this experiment is to study the behaviour of the relevant observables in the fission fragments to find features around particular Z or N numbers that might show the role of shell effects at high excitation energy in this region of nuclei. In this contribution, preliminary results on the analysis of the fission fragments will be presented.

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Searching for the Anomalous Internal Pair Creation in ^{8}Be

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In the 1950s, Devons et al. started to carry out experiments in light nuclei that aimed to measure the angular distribution of the relative angle in the emission of the leptons in the Internal Pair Creation (IPC) process. The results were consistent with the Model of Rose published in 1949. In 2016, Krasznahorkay et al. reported the breakthrough of an anomaly in the IPC of ^{8}Be. An unexpected angular correlation distribution in the emission of the pair e^+e^- was found in the isoscalar magnetic dipole transition (18.15 MeV state ($J^\pi = 1^+$, T=0) $\rightarrow$ ground state ($J^\pi = 0^+$, T=0)). According to theoretical calculations performed with the model of Rose, the angular correlation distribution drops quickly with the relative emission angle of the leptons. In contrast, the Hungarian group reported a peak-like behavior at large angles. This result has been interpreted as the signature of the emission of a previously unknown neutral isoscalar particle with a mass of 16.70$\pm$0.35(stat)$\pm$0.5(syst) MeV/c^2 and $J^\pi = 1^+$.

The present work reports the development of a dedicated array to study this anomaly at the Laboratori Nazionale di Legnaro (Istituto Nazionale di Fisica Nucleare, Italy). The project aims to measure the angular correlation distribution of the emission of the pair e^+e^- from the transition studied in ^{8}Be at the Atomki Laboratories. The detector unit is a telescope manufactured with the plastic scintillator EJ200. The in-beam commissioning of the setup demonstrated that the array is able to measure the lepton pair in coincidence and reconstruct the energy of the electromagnetic transition in the IPC process. Furthermore, the ΔE layer consists of a system of a double layer of 10 bars designed to detect the incident position of the particles. The IPC of the transition $0^+ \rightarrow 0^+$ in ^{16}O has been studied as a first case. This transition is used as a calibration point of the detectors since the cross-section is orders of magnitude higher than the one in ^{8}Be. During the end of November 2023 and the end of April 2024, the former experiments were carried out at the AN2000 Accelerator. LiF targets from 50-950 μm/cm^2 have been irradiated with a 1.06-1.09 MeV proton beam and a $\sim$500 nA current. The population of the state of interest and the integrity of the target were monitored with a 3$\times$3 in^2 $LaBr_3$ detector. The preliminary results in the study of the isovector and isoscalar magnetic dipole transitions in ^{8}Be are shown.

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Probing the fp-shell wave-functions with the MED in JYFL

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Studying the nuclei along and near the N=Z line is the best way to find answers to some fundamental questions in nuclear structure, such as charge-dependence of the nuclear interaction or the role of the proton-neutron pairing. Despite our deep understanding of the electromagnetic interaction, the differences in the binding energies in mirror nuclei cannot be reproduced theoretically, thus pointing that the ISB could arise also from the residual nuclear interaction.
Cross-shell particle-hole excitations from the sd to the fp shells in the mid-shell 42≤A≤54 nuclei generate rotational bands of non-natural parity, particularly sensitive to the electromagnetic spin-orbit interaction. In the 43Sc-43Ti mirror pair such positive-parity bands extend up to 27/2+. There is a competition between proton-hole and neutron-hole excitations from the sd orbitals, and the MED are very sensitive to cross-shell single-particle excitations, which can be used to determine the type of nucleons excited across the shell gap.
To explore this phenomenon, we performed spectroscopic studies, extending the level scheme of 43Ti up to the 25/2+ state. Excited states of 43Ti were populated in a fusion-evaporation reaction in JYFL, Jyvaskyla. The prompt γ-rays were detected with JUROGAM 3 spectrometer while the evaporation residues were selected with MARA separator. We find that the competition between protons and neutrons promoted from the sd shells yields, at medium-high spin, MED as high as 250 keV. This increase of the MED is interpreted within state-of-the-art large-scale shell model calculations as driven by the competition between the promotion of a proton and of a neutron across the shell gap.

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Lifetime Measurements in neutron-rich Pt Isotopes

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The present work reports the status of lifetime measurements and in-beam spectroscopy of neutron-rich Pt isotopes. The experiment aims to study the shape evolution in this region. These nuclei are expected to be more spherical near shell closure, but there is a lack of data to support this theoretical prediction. The population of the states of interest has been carried out by the multi-nucleon transfer (MNT) reaction technique with a beam of ^{136}Xe impinging on a ^{198}Pt target, with a 1133 MeV energy. The target and degrader have been placed in the plunger device in reversed configuration. The PRISMA separator has been used to identify the beam-like fragments, and AGATA to detect γ rays of their binary partners.

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Direct transfer reaction studies with GRIT at SPES

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The GRIT European collaboration aims to build a new generation Silicon detector array for optimal study of direct nuclear reactions induced by radioactive-ion beams.

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Results on the lifetimes measurements around 82Nb using knock out reactions

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Nuclear structure is a challenging topic as we deal with systems that are not small enough to use standard quantum methods, nor large enough for statistical mechanics. Nuclei with similar numbers of neutrons and protons ($N \approx Z$) exhibit competition between different shapes, such as oblate and prolate, leading to phenomena like shape coexistence. These $N \approx Z$ nuclei are particularly interesting for studying proton and neutron interactions within specific orbitals. The region around $A \approx 80$ near the $N = Z$ line is not well explored due to the difficulty in reaching it with current facilities.

A common approach to compare theoretical models and experiments is to measure transition probabilities between excited states. The reduced quadrupole transition probability $B(E\lambda; J_i \to J_f)$ is related to the lifetime of the excited state, which can be measured down to a few picoseconds using the Recoil Distance Doppler Shift (RDDS) method. This method relates the state lifetime to the energy splitting generated by a degrader placed at a known distance.

To study the region around ^{84}Mo, ^{82}Nb and ^{82}Zr, the e19034 multinucleon knockout experiment was performed at MSU. A ^{92}Mo primary beam was impinged on a beryllium target, and the produced nuclei were identified and separated by the A1800 spectrometer using TOF measurements before reaching a second beryllium target for the knockout reaction. The different channels produced, such as -2n and -1p-3n, were separated by the S800 spectrometer. Surrounding the secondary target, the GRETINA array provided high-resolution gamma-ray energy measurements.
In this work we will present part of the results from this experiment and their implications for the $N = Z$ vicinity.