HIGS PAC 2016 Approved Experiments

P-01-16

Experiment: Constraints on $0\nu\beta\beta$ decay matrix elements from novel decay branches of the scissors mode of ^{150}Nd

Spokesperson: Tobias Beck – Darmstadt, tbeck@ikp.tu-darmstadt.de

Hours: 80

Abstract

We propose to investigate the electromagnetic coupling of the 1^+_{sc} levels of the scissors mode at around 2.994 MeV to the β-band head of ^{150}Nd using a $\gamma\gamma$-coincidence setup at the HIGS facility. Combining the unique quasi-monochromatic and linearly polarized photon beam at HIGS with a coincidence setup composed of a LaBr3:Ce and HPGe detector array, the aforementioned states can be populated selectively and their decay pattern can be observed in high precision. Recently, an enhanced M1 decay branch of the scissors mode to the first excited 0+ state was identified in the nucleus ^{154}Gd. This property of the scissors mode implied an increased matrix element for the neutrinoless double- decay to the 0^+_2 state of the daughter nucleus. Together with the ^{150}Sm data already at HIGS we will be able to test the theoretical prediction which expects a dominant $0\nu\beta\beta$-decay branch from ^{150}Nd to the 0^+_2 state of ^{150}Sm.

P-03-16

Experiment: Constraining nuclear matrix elements for ($0\nu\beta\beta$) decay from branching ratios of the scissors mode in the $\beta\beta$-partners ^{82}Se and ^{82}Kr

Spokesperson: Udo Gayer – Darmstadt, ugayer@ikp.tu-darmstadt.de

Hours: 65

Abstract

A potential experimental observation of the neutrinoless double-beta ($0\nu\beta\beta$) decay would finally fix neutrino masses and determine the character of their antiparticles. The extraction of neutrino masses from $0\nu\beta\beta$ decay requires precise knowledge of the nuclear matrix elements (NMEs) which are involved in the process. High-precision studies of mixed-symmetric dipole states, for example the scissors mode in deformed nuclei, can yield important information on both pp-, nn- and pn-interactions in a nucleus. Such a study of the decay behavior of the scissors mode was done for the $0\nu\beta\beta$ decay partner nuclei ^{154}Gd and ^{154}Sm. It was shown that shape-coexistence in ^{154}Gd opens up a new decay branch via the first excited 0+ state which enhances the $0\nu\beta\beta$ decay rate in theoretical calculations. Recently, the $0\nu\beta\beta$ partner nuclei ^{82}Kr and ^{82}Se have been discussed as candidates for the SuperNEMO experiment. For none of these two nuclei, the decay behavior of the scissors mode has been investigated. Therefore, theoretical calculations of the NMEs for $0\nu\beta\beta$ decay lack important experimental constraints. To clarify the nuclear physics aspect of this exotic decay process, we propose a high-precision study of these two isobars.

P-04-16

Experiment: Optimum doorway states for (γ,γ') production of the high-spin isomer ^{195m}Pt

Spokesperson: Ulli Koster – Institut Laue-Langevin, koester@ill.fr

Hours: 64

Abstract

The $i_{13/2}$ isomer ^{195m}Pt decays with a half-life of 4 days under emission of conversion electrons and a cascade of Auger electrons. It is one of the most attractive isotopes for Auger electron therapy, but due to its 99 keV gamma ray emission it can also serve as SPECT radiotracer for Pt compounds. Unfortunately, reactor production with thermal neutrons is disfavored by small production and very large destruction cross-sections. An alternative production route was proposed using resonant photo-activation (γ,γ') via suitable doorway states. Doorway states are excited states that are connected by a direct transition to the ground state and by a gamma ray cascade to the isomeric state. Similar to a three-level system in atomic physics they allow pumping to the metastable state. In the EXILL campaign we have identified potential doorway states via the surrogate reaction $^{194}Pt(n,\gamma)$ at 1313, 1348, 1561, 2035, 2311, 2351 and 2590 keV. Now we want to measure the photo-activation cross-sections at these energies. The experiment is performed by photo-activation of Pt foils at HIGS, followed by off-line gamma ray spectrometry assay of the foils at Duke University and, for very low activities, in addition at low-level gamma ray spectrometry labs in France.

P-05-16

Experiment: Model-independent determination of isospin mixing in mirror nuclei

Spokesperson: Sorin Pascu – National Institute for Physics and Nuclear Engineering, Bucharest Romania, spascu@tandem.nipne.ro

Hours: 100

Abstract

We propose to measure the decay pattern of several $5/2^+$ states with isospin quantum number T=3/2 in ^{35}Cl to investigate the isospin mixing in mirror nuclei in a model-independent way from the relative strength of E1 transitions. One of the most prominent examples of isospin mixing is the mirror pair ^{35}Cl-^{35}Ar, where a strong asymmetry has been observed for the decay of the first 7/2- state, which is believed to arise from a mixing of T=1/2 and T=3/2 states. In a recent experiment performed in Bucharest we have measured the lifetime of this state in ^{35}Ar and established that the corresponding B(E1) asymmetry of the mirror doublet scales with the decay of the isobar analog state in ^{35}Cl. This fact represents a solid argument in favor of a description of isospin mixing as arising from a mixing mainly between discrete states. This mirror doublet exemplifies a fortunate case where the contribution of the high-lying giant dipole resonance seems to be rather reduced, although its effect cannot be excluded. By assuming this scenario, it was shown that given enough experimental information on appropriate E1 transition strengths, the isospin mixing in the initial and final state could be determined in a model-independent way. Currently, the best candidate is the pair of mirror nuclei ^{35}Cl-^{35}Ar, where only a few reduced B(E1) strengths are missing. The main goal of this proposal is to investigate the complete decay of the 5/2+ states with T=3/2 in ^{35}Cl in order to determine for the first time the ratio between the isospin mixing in the initial and final states. If T=3/2 to T=3/2 transitions can be measured, the full values rather than the ratio of the mixing coefficients will be determined for the first time. Furthermore, we would like to perform an exploratory investigation for the decay of the 3/2+ state with T=3/2 at E=5.654 MeV. For this level it is interesting to determine the M2 matrix element to the first 7/2- state. Such M2 strength will allow an independent verification for the isospin mixing of ^{35}Ar-^{35}Cl doublet in the case of M2 transitions.

P-06-16

Experiment: Low-lying dipole strength of ^{120}Sn

Spokesperson: Deniz Savran – GSI, d.savran@gsi.de

Hours: 80

Abstract

We propose to investigate the low-lying dipole strength in the nucleus ^{120}Sn using the γ^3 setup at HIGS. The experiment aims to determine the full photon absorption cross sections as well as provide details on the E1/M1 ratio and the decay behavior of photo-excited states up to the neutron separation energy. Recently, results from inelastic proton scattering experiments have been reported for ^{120}Sn, showing a much larger amount of dipole strength in the excitation energy region 5 MeV to 9 MeV than observed in a previous NRF experiment. Up to a factor of ten larger B(E1) values are extracted from the (p,p') experiment. The existing NRF data was measured with bremsstrahlung only and does include only the strength of resolved excitations decaying back to the ground state. It is known, that depending on the level density and excitation energy a considerable amount of strength is contributed by unresolved transitions, either to the ground state or to excited states. However, even taking this into account, the large difference between the NRF and the new (p,p') data is unexpected. Understanding this difference is of mandatory importance not only for the case of 120Sn, but also to investigate the reliability of both experimental approaches in general. We therefore propose to use 120Sn as a test case with high precision data from both experimental methods.

The γ^3 setup at HIGS allows to provide the necessary precision to contribute the NRF data for the comparison. We have shown that the high efficiency of the setup together with the monochromatic character of the photon beam allows not only to determine the full photo absorption cross section, but also to disentangle E1 and M1 contributions as well as provide important information on the decay properties of the photo-excited states. It is currently the only available setup allowing this kind of NRF experiment.

P-07-16

Experiment: Accurate determination of the B(M1) strength of the 9.757 MeV state in ^{40}Ar.

Spokesperson: Werner Tornow – TUNL, tornow@tunl.duke.edu

Hours: 100

Abstract

The M1 character of the previously known 9.757 MeV state in ^{40}Ar has been determined by Li at al. The associated experiment, proposed by N. Pietralla, was done in the year 2005 at HIGS. Prior to this experiment, the spin and parity of the 9.757 MeV state was unknown. Its strength has been measured by Moreh et al. Li et al. reported for the spin-flip M1 strength of the 9.757 state the value of B(M1) $\uparrow$=0.148(59) μ^2_N

Following a request from A. Hayes and G. Garvey, LANL, we propose to perform a new measurement of the M1 strength of the 9.757 MeV state in 40Ar. The goal is to reduce the present uncertainty of 40% to 10%. A 2.1 cm diameter stainless steel sphere filled to 200 atm with natural argon gas and the standard 60% HPGe NRF setup will be used. We plan to use in addition to four 60% HPGe detectors also four 3” x 3” LaBr detectors, which have a factor of six larger photo-peak efficiency. Due to the absence of other M1 states in the vicinity of the 9.957 MeV state, the estimated 2% energy resolution of the LaBr detectors should not be a disadvantage compared to the superior energy resolution of the HPGe detectors. A ^{238}U fission chamber will be employed for γ-ray flux determination.

P-08-16

Experiment: Compton Scattering from ^{3}He.

Spokesperson: Gerald Feldman – GWU, feldman@gwu.edu

Hours: 341

Abstract

We propose to measure the Compton scattering cross section for ^{3}He at 100 and 120 MeV using circularly polarized photon beams from HIGS incident on the new cryotarget that has recently been commissioned. The scattered photons will be detected in the large HINDA array of NaI detectors at eight scattering angles surrounding the target in a horizontal plane. Our primary objective is to obtain information about the isospin-averaged nucleon polarizabilities. The rationale for using ^{3}He for this purpose stems from the fact that the Compton cross section scales roughly as Z^2 at energies below ~80 MeV and closer to Z above that, and we therefore hope to exploit the sensitivity to the polarizabilities in the case of higher cross section (that is, higher than the Z=1 case of the proton or the deuteron) where we can determine the cross section with relatively small statistical uncertainties using the high intensity HIGS photon beam.

The Compton scattering reaction on 3He has never been measured, so this would constitute an entirely new data set in the realm of nuclear Compton scattering. At HIGS, such an experiment was not possible before, due to the lack of a cryogenic target system. While that new target will indeed enable experimental efforts on hydrogen and deuterium, we see the unique prospect of extending this work to a Z=2 nucleus which is now calculable within the framework of Effective Field Theory (EFT).

P-10-16

Experiment: $^{7}Li(\gamma, t)^{4}He$ above E = 4 MeV

Spokesperson: Catalin Matei – ELI-NP, catalin.matei@eli-np.ro

Hours: 80

Abstract

We propose to measure the $^{7}Li(\gamma, t)^{4}He$ reaction at γ-ray energies between 4 and 11 MeV using the ORRUBA array of position sensitive silicon strip detectors. The reaction is important for testing our understanding of the mirror alpha capture reactions 3H(α,γ)^{7}Li and 3He(α,γ)7Be and for verifying several recent theoretical predictions. The solution to the discrepancy between the calculated and observed primordial 7Li abundance could still be come from the 3H(α,γ)^{7}Li reaction under different conditions during Big-Bang Nucleosynthesis. Although most measurements over the last 30 years have concentrated in an energy range below 1.5 MeV, measurements at higher energies could potentially restrict the extrapolation to astrophysically important energies. The primary goal of the measurement is to determine cross sections and angular distributions between 4 and 11 MeV.

P-11-16

Experiment: Investigation of levels of astrophysical relevance in ^{15}N

Spokesperson: Tamas Szucs – Int. Nuclear Research (MTA Atomki), Hungary,
szucs.tamas@atomki.mta.hu

Hours: 40

Abstract

The capture of protons, neutrons, and alpha particles on the unstable nucleus ^{14}C plays an important role in various nucleosynthesis scenarios. The present proposal suggests to investigate the properties of two J = 3/2 states in ^{15}N at excitation energies of about 10.7 MeV and 10.8 MeV which are located slightly above the proton separation threshold, but below the neutron and α separation thresholds of ^{15}N. Hence, these states appear as low-energy resonances in the $^{14}C(p,\gamma)^{15}N$ reaction, and their resonance strengths ωγ enter directly into the determination of the astrophysical reaction rate $N_A\langle\sigma v\rangle$.

P-12-16

Experiment: Measurement of the Tensor Analyzing Power in Deuteron Photodisintegration between E = 4 MeV and 20 MeV

Spokesperson: Blaine Norum – UVa, ben@uva.edu

Hours: 204

Abstract

We are proposing to measure the tensor analyzing power $T_{20}(\theta_n)$ in deuteron photodisintegration between photon energies of 4 MeV and 20 MeV , an energy range not covered in any previous measurement. Several measurements at laboratories around the world over the last 40+ years have shown disagreements with our current theoretical descriptions of the deuteron. These include measurements of d(p, pp)X from the Moscow Meson Facility, of d (γ, π+γ') at the LEGS facility at Brookhaven, of d (γ,n) at Yale University, of d(e, e'p) TH-Darmstadt, as well as d (γ, n) at HIGS. A common feature of these measurements is the indication of a notable discrepancy when the two-nucleon final state has an internal energy of about 9 MeV ; the measurements at LEGS strongly indicate that this discrepancy has an electric, as opposed to magnetic, origin. The tensor analyzing power is particularly sensitive to the d-state in the deuteron. In addition, the best current calculations indicate that 1) only the even order terms in the Legendre expansion of T_{20} (θ_n) are expected to contribute significantly; 2) the dominant contribution to the zeroth order term in the Legendre expansion of T_{20} (θ_n) comes from the M1($^1S_0$) amplitude; 3) the second and fourth order terms depend almost completely on electric multipoles. By measuring the angular distribution of $T_{20}(\theta_n)$ we will isolate these three terms, the latter two being particularly sensitive to the suggested electric origin of the discrepancies. This will allow us to make unprecedented tests of the best available calculations across this energy range and to further investigate the anomalous behavior near 9 MeV in the residual two-nucleon system.

The measurements will use the fridge of the HIFROST polarized target augmented by a new target cell and related microwave equipment currently under development at UVA. These additions will make possible the tensor polarization of the target while keeping the vector polarization near zero. The Blowfish neutron detector array and the Five-Paddle Beam monitor will also be used. The LUCID-ROOT system will be used for data acquisition.

The measurements will represent the first ever use of a solid, (almost) purely tensor-polarized deuteron target. Not only will it enable us to measure previously unattainable polarization observables, it will provide an excellent opportunity for a graduate student to gain experience with this revolutionary experimental technology.

P-13-16

Experiment: Measurements of Exclusive Cross Sections for Three-body Photodisintegration of ^{3}He at 15 MeV

Spokesperson: Calvin Howell – TUNL, howell@tunl.duke.edu

Hours: 100

Abstract

We propose to measure exclusive cross sections for three-body photodisintegration of ^{3}He for several kinematic arrangements of the emitted nucleons. The experimental setup will allow for coincident detection of both proton-neutron and proton-proton particle pairs, i.e., the $^{3}He(\gamma,pn)$. This experiment is part of the ongoing research at TUNL that explores long-range effects of three nucleon forces using few-nucleon reactions. Photonuclear reaction data are important for evaluating treatments of meson-exchange currents and the Coulomb interaction in ab-initio few nucleon calculations. Though there are considerable data for 3He photodisintegration, this experiment will provide the first cross-section data for exclusive three-body photodisintegration at low energies. The data produced in this experiment will enable, for the first time, evaluation of ab-initio ^{3}He photodisintegration calculations in highly constrained regions of kinematic phase space. Also important, the main design features of the gas targets, charged-particle collimator array, and detector setup are the same as those to be used the proposed tritium photodisintegration experiment, (P-02-13). Execution of the proposed exclusive measurements for ^{3}He photodisintegration is a necessary and important step in developing the more technically challenging tritium photodisintegration measurements.

HIGS PAC 2014 Approved Experiments (Note PAC did not meet in 2015)

P-01-14

Experiment: Constraints on $0\nu\beta\beta$ decay matrix elements of ^{150}Nd from a nocel decay channel of 1+ scissors mode of ^{150}Sm

Spokesperson: Volker Werner – Darmstadt, vw@ikp.tu-darmstadt.de

Hours: 60

Abstract

We propose to investigate the electromagnetic coupling of the 1^+_{sc} level of the scissors mode at 3.082 MeV of ^{150}Sm to the 0^+_2 state. Recently, we discovered the corresponding decay in the nuclei $^{152;154;156}$Gd and showed that this decay channel is of great importance to constrain $0\nu\beta\beta$ ^{154}Sm $\rightarrow$ ^{154}Gd decay matrix elements within the Interacting Boson Model. For a reliable description of the 0 $\nu\beta\beta$ ^{150}Nd$\rightarrow$^{150}Sm decay process detailed information about low-lying states is needed, such as the scissors mode states. We intend to make use of the mono-energetic γ-ray beam at the High Intensity γ-Ray Source (HIGS) to populate the scissors mode state in ^{150}Sm. The scissors mode of ^{150}Sm has a low fragmentation and is almost entirely concentrated in two 1^+ states at 3.082 and 3.113 MeV. Previous Nuclear Resonance Flourescence (NRF) measurements give their widths to be Γ^2_0/Γ = 31(3) and 13(2) meV, respectively.

P-02-14

Experiment: On the low-energy enhancement: The γ-ray strength functions in ^{50}Ti and ^{52}Cr

Spokesperson: Vera Derya – Koeln, derya@ikp.uni-koeln.de

Hours: 125

Abstract

We propose to study the γ-ray strength function (γSF) in consideration of the average γ-decay behavior of (mainly) dipole excitations in the two *fp* shell nuclei ^{50}Ti and ^{52}Cr. A precise knowledge and understanding of the γ-ray strength function over a wide range of mass numbers is crucial for the correct theoretical prediction of nucleosynthesis processes and solar abundances since network calculations strongly depend on this as an input parameter. In the *fp* shell nuclei region, an unexpected low-energy enhancement of the strength function was observed by means of the Oslo method. The occurrence of this so-called upbend was confirmed in an independent measurement in the medium-mass region. Up to now, there are opposing physical interpretations of the upbend. Recently, the dipole character of the enhancement was proven whereas the radiation character and the question of which nuclei show the upbend remain unresolved.

The HIGS facility provides a selective excitation in multipolarity (dipole favored) and energy (quasi mono-energetic) which allows for a detailed investigation of the composition of excitations and the corresponding γ-ray transitions between these excitations. Sensitivity to the observation of these γ-ray cascades is further increased by using the γ- coincidence method in the high-efficiency γ^3 setup as it was previously used for the γ^3 campaigns in 2012 and 2013.

The measurements of the γSF in the semi-magic N = 28 isotones ^{50}Ti and ^{52}Cr using the γ^3 setup at HIGS will allow studying the eect of adding two protons to a neutron-magic nucleus on the γSF. Furthermore, a possible low-energy enhancement can be tested with additional observables in a model-independent way.

P-03-14

Experiment: Interplay of magnetic dipole strength and pygmy dipole strength in ^{54}Fe

Spokesperson: Ronald Schwengner – IRP, HZ Dresden-Rossendorf, r.schwengner@hzdr.de

Hours: 120

Abstract

An improved experimental and theoretical description of photonuclear reactions and the inverse radiative-capture reactions is very important for the understanding of astrophysical processes. Dipole strength functions are an important ingredient for the calculation of reaction cross sections within the statistical model. Therefore, precise measurements of dipole strength distributions are needed for a correct determination of those cross sections. Our earlier photon scattering studies using the HIGS facility as well as the bremsstrahlung facility at the ELBE accelerator of the Helmholtz-Zentrum Dresden-Rossendorf (HZDR) have evidenced enhanced E1 strength below the neutron-separation energy that is considered as a pygmy dipole resonance. Moreover, we have shown in studies of the molybdenum and xenon isotopic chains that the neutron excess mainly drives the evolution of the strength in the pygmy region, whereas nuclear deformation plays a minor role only. Calculations on the basis of statistical reaction models have shown that very pronounced pygmy strength increases the (n,γ) cross section compared to cross sections calculated using phenomenological descriptions of strength functions.

In contrast to the various studies of E1 strength in the pygmy region, information about M1 strength is rather scarce. A study of M1 strength in ^{90}Zr at HIGS has revealed a resonance-like structure around 8 MeV. Its contribution to the absorption cross section amounts to about 10% of that of the E1 strength. A similar finding results from HIGS data for xenon isotopes currently under analysis. The situation seems to change when going to lighter nuclides, such as the ones in the iron-nickel region. In 56Fe, 58Ni, and 60Ni, several strong isolated M1 excitations have been observed. This raises several questions: What is the magnitude of the M1 strength relative to the E1 strength in nuclides around the mass-60 region? What is the contribution of strength in the quasicontinuum that was not considered so far? Is the M1 strength distribution compatible with phenomenological approximations used as input strength functions in codes calculating reaction rates on the basis of the statistical model? What is the influence of nuclear structure, for example of nearby shell closures, on the M1 strength?

We propose to study the M1 and E1 distribution in ^{54}Fe, a nuclide with two proton holes in Z=28 and a closed N=28 neutron shell. We expect to obtain novel information answering the questions just mentioned.

P-04-14

Experiment: Investigation of the s-process branch-point nucleus ^{86}Rb using the γ^3 setup

Spokesperson: Kerstin Sonnabend – Frankfurt, sonnabend@ikp.uni-frankfurt.de

Hours: 100

Abstract

The branch-point nucleus ^{86}Rb determines the isotopic abundance ratio ^{86}Sr/^{87}Sr in s-process nucleosynthesis. Thus, stellar parameters such as temperature and neutron density and their evolution in time as simulated by modern s-process network calculations can be constrained by a comparison of the calculated isotopic ratio with the one observed in SiC meteoritic grains. To this end, the radiative neutron-capture cross section of the unstable isotope ^{86}Rb has to be known with good accuracy.

Since a direct measurement is prohibited by the half-life of ^{86}Rb of only $t_{1/2}$ = 18.7 d, the nuclear physics input to a calculation of the cross section has to be measured to adapt the neutron capture cross section of the branch-point nucleus experimentally. The major ingredient is the γ-ray strength function of ^{87}Rb which we here propose to determine using the γ^3 setup. The low-energy part will be derived from photon-scattering for which this setup was designed and successfully tested. The high-energy part stems from photo-neutron reactions for which the γ^3 setup will be equipped with fast neutron detectors.

P-05-14

Experiment: Search for the 3951.7 keV state in ^{76}Ge

Spokesperson: Werner Tornow – TUNL, tornow@tunl.duke.edu

Hours: 24

Abstract

The decay of the 3951.7 keV state in ^{76}Ge provides a 2041.7 keV γ-ray which may be indistinguishable from the potential 2039.9 keV signal expected for 0νββ of ^{76}Ge. A firm spin and parity assignment of the 3951.7 keV state does not exist. The tentative assignment is (1,2+). According to our knowledge, neutron irradiation experiments on ^{76}Ge have not seen the de-excitation of the 3951.7 keV state, which has been observed only after β-decay of ^{76}Ga. If this state is indeed a dipole state, it could be excited by photons from the 0+ ground state of ^{76}Ge. We propose to perform a Nuclear Resonance Fluorescence experiment at 3950 keV incident photon energy to search for the 3951.7 keV state.

P-06-14

Experiment: Search of the onset of Pygmy Dipole Resonance in the A = 50 mass region: The cases of ^{50}Ti, ^{50}Cr, and ^{54}Cr

Spokesperson: Markus Zweidinger – Darmstadt, zweidinger@ikp-tu-darmstadt.de

Hours: 70

Abstract

We started a campaign to systematically investigate the low-lying dipole strength distribution in the A = 50 mass region by means of nuclear resonance fluorescence (NRF) measurements at TU Darmstadt. As part of this campaign, we propose to study the complete low-lying dipole strength of ^{50}Ti as well as $^{50;54}$Cr for unambiguous parity assignments, making use of the intense photon beams at HIGS. The expensive target material has been borrowed from the Oak Ridge National Laboratory for a time period of one year ending February 2015. In May 2014, we are going to perform NRF experiments at TU Darmstadt, where we determine the overall dipole strength distributions of all three nuclei up to their particle separation thresholds using bremsstrahlung. The linear polarization of the photon beam at HIGS allows the subsequent determination of parity quantum numbers of dipole excited states. Since the photon beam at HIGS is quasi-monoenergetic, it is also possible to investigate inelastic decay paths of the dipole excited states. The assignment of electric or magnetic character to the decay of dipole excited states is of high importance for the analysis of two phenomena of the low-lying dipole strength: In the nucleus ^{48}Ca first hints for the onset of the so-called pygmy dipole resonance (PDR) were found. Recently, results of an NRF measurement on the N = 28 isotone ^{52}Cr supported the observation that the PDR begins to form in the A ≈ 50 mass range. To get more information on the onset of the PDR, the investigation of electric dipole strength in nuclides of the A = 50 mass region with various combinations of neutron numbers around the N = 28 shell closure is desirable. Furthermore, for the comparison with appropriate microscopic model calculations, such as the quasiparticle phonon model (QPM), knowledge of the parity quantum numbers of the observed states is crucial. Additionally, because of the shell structure in the mentioned mass region, magnetic dipole transitions occur that are interpreted as spin-flip transitions. Theoretical calculations in the framework of the QPM show a resonant-like structure of these spin-flip transitions at an energy near 9 MeV i.e., in the same energy range as the PDR. Therefore, the clear assignment of parity quantum numbers is required to distinguish the two phenomena.

P-09-14

Experiment: Paving the Way for Time-of-Flight Based Low-Energy Neutron Spectroscopy in (γ,n) and (γ,γ'n) Reaction Studies

Spokesperson: Werner Tornow – TUNL, tornow@tunl.duke.edu

Hours: 100

Abstract

Neutron spectroscopy in the 10 keV to 200 keV energy range is a challenging task. This task becomes even more challenging at HIGS, where the photon flux scattered from any target into the direction of a neutron detector is orders of magnitude larger than the neutrons produced in the target. As a result, low-energy neutron measurements at HIGS have been limited to counting neutrons with a 3He based proportional counter array, which does not provide any information on the incident neutron energy. Recent experiments using this approach are the ^{9}Be(γ,n)^{8}Be and ^{86}Kr(γ,n)^{85}Kr measurements of Arnold et al. and Raut et al, respectively. Only the early work of Tornow et al. employed a technique that allowed for neutron spectroscopy down to En=90 keV by using the time-of-flight (TOF) technique and special liquid scintillator neutron detectors for studying the ^{2}H(γ,np) reaction. These detectors were recently used again at HIGS by deBoer et al. for investigating the level structure of ^{26}Mg via the ^{26}Mg(γ,n)^{25}Mg reaction. Furthermore, in auxiliary measurements at Notre Dame it was shown that the intrinsic efficiency of these detectors is still 25% even at neutron energies as low as 50 keV [4]. In this proposal we plan to revisit the ^{86}Kr(γ,n)^{85}Kr reaction. However, this time we propose to not simply detect neutrons, but to measure their energy as well using the TOF technique by employing the time structure of the HIGS γ-ray beam in conjunction with the liquid scintillator detectors of Tornow et al. We also propose to explore the usefulness of the high-pressure ^{3}He/Xe gas scintillators of Tornow et al. for neutron TOF measurements at neutron energies below 50 keV.

This proposal has to be seen as a "warm-up" for HIGS proposals which rely on the feasibility of low-energy neutron spectroscopy and in some cases even γ-n coincidences by adding neutron detectors to the HPGe and LaBr γ-ray detectors of the γ^3 experimental setup in the UTR. Based on his experience with neutrons and as the initiator of the NRF activities and γ-activation and γ-imaging studies at HIGS (called DFELL in 1996) and custodian of the experimental setup in the UTR, it seem natural that the spokesperson of the present proposal also leads the effort to pave the way for NRF and nuclear astrophysics related experiments requiring low-energy neutron spectroscopy.

P-10-14

Experiment: A Study of the Mass Dependence of the Isovector Giant Quadrupole Resonance in Sn

Spokesperson: Gerald Feldman – GWU, Feldman@gwu.edu

Hours: 135

Abstract

We propose a high precision measurement of the isovector giant quadrupole resonance (IVGQR) in ^{112}Sn using linearly polarized Compton scattering. The experimental signal of the IVGQR is observed via interference with the tail of the well-known giant dipole resonance. Our discovery of the fact that this interference term, when observed in the ratio of the perpendicular to the parallel yields, flips sign when going from forward to backward angles leads to a precise result for the parameters of the IVGQR . The nearly 100% polarization and quasimonoenergetic nature of the HIGS beam allows a clear determination of this effect over a wide energy region, from which the IVGQR excitation energy can be extracted. This technique has been successfully applied in a previous experiment at HIGS to measure the IVGQR in ^{209}Bi with an uncertainty of 0.13 MeV. Preliminary analysis from a recent measurement of the IVGQR in ^{124}Sn at HIGS has achieved a similar level of precision. A measurement of the IVGQR in ^{112}Sn, along with the previous measurement of ^{124}Sn, will establish the slope of the mass dependence of the IVGQR centroid energy in the Sn isotopic chain. This slope, together with the high-mass value for ^{209}Bi, will provide a solid basis for extracting a tight constraint on the symmetry energy term in the nuclear matter equation of state.

P-11-14

Experiment: $^{16}O(\gamma;\alpha)^{12}C$ Above E= 10 MeV

Spokesperson: Carl Brune – Ohio U, brune@ohio.edu

Hours: (200)

Abstract

It is proposed to study the $^{16}O(\gamma;\alpha)^{12}C$ reaction with the Optical Time Project Chamber at HIGS, for γ-ray energies between 10 and 13.5 MeV. The determination of the angular distribution of the particles will allow the E1 and E2 multipole components of the reaction to be separated. The primary goal of the measurement is to determine the cross sections between known resonances, which are poorly determined at this time. Another goal is to measure cross sections around the peaks of the resonances. The time-reversed reaction, $^{12}C(\alpha;\gamma)^{16}O$, plays a very important role in helium burning in massive stars. The cross section at helium-burning energies, i.e., around E_{cm} = 300 keV, must be determined using semi-empirical theory and extrapolation from higher energies and remains a major uncertainty in the modeling of the evolution of massive stars. The proposed measurements would be very helpful in R-matrix modeling of the reaction used for the extrapolation. The data would allow more states to be explicitly included, which diminishes the importance of the background contribution, leading to reduced uncertainties. In particular, the nature of the interference between resonances of the same spin and parity can be determined.

HIGS PAC 2013 Approved Experiments

P-01-13

Experiment: First Measurements of Spin-Dependent Differential Cross Sections from $^{3}\boldsymbol{He}(\gamma,p)d$ reaction at Incident Photon Energies of 25 and 30 MeV

Spokesperson: Haiyan Gao – TUNL, gao@tunl.duke.edu

Hours: 250

Abstract

The experiment on two-body photodisintegration of 3He with double polarizations will provide data that can be used as testing ground for novel three-body calculations. It also contributes to the determination of the Gerasimov-Drell-Hearn (GDH) integral from the two-body break up threshold to the pion production threshold. We request a total beam time of 370 hrs of 100% circularly polarized γ-ray beam from the HIGS facility to perform the first measurement of the spin-dependent differential cross sections from the two-body break up of 3He at incident photon energies of 25 and 30 MeV. In this proposal, we discuss the motivation for this experiment, followed by a summary of the results of the test run approved by HIGS PAC-11. We present our time request for the new measurements at the end.

P-02-13

Experiment: Cross-section Measurements of Two and Three-body Photodisintegration of the Triton and Search for a Bound Dineutron State

Spokesperson: Calvin Howell – TUNL, howell@tunl.duke.edu
Hours: 360

Abstract

The main goal of this experiment is to provide photodisintegration data for a few-nucleon system in which the Coulomb force is absent. There are several reasons we think these measurements are important. This experiment will provide the first differential cross sections for two-body photodisintegration of the triton and as such will enable comparisons of data to ab initio three-nucleon calculations without the added computational complication of having to apply approximate methods to treat the Coulomb interaction. For instance, the sensitivity of the cross section for photodisintegration of 3He to the Coulomb interaction is comparable to the influence of meson-exchange currents on this observable. Having data that are free of the Coulomb force will enable theorists to focus attention on the nuclear interaction features of the calculations, including the treatment of the photon interactions with the meson-exchange currents. Also, the proton energy spectra measured in this experiment will enable the first determination of the $^1S_0$ neutron-neutron scattering length using photodisintegration. Measurement of the neutron energy spectrum will allow concurrent determination of the $^1S_0$ np scattering length. A more speculative pursuit is the search for evidence of a bound di-neutron state. This aim imposes stringent requirements on the energy resolution of the experiment. Resolving a di-neutron bound state from the three-nucleon breakup continuum in the proton energy spectrum requires the resolution of the proton energy measurement to be less than the binding energy of the di-neutron. The thickness of the tritium targets and the diameter of the collimator that defines the gamma-ray beam energy resolution and size on target have been set to have measurement sensitivity of a bound di-neutron with binding energy down to about 300 keV without substantially sacrificing the main objectives of the experiment. Also, R&D runs should produce publishable data for photodisintegration of ^{3}He.
We propose to measure the cross sections for two- and three-body photodisintegration concurrently by detecting the emitted protons and deuterons. The measurements will be carried out with a linearly polarized gamma-ray beam at 12.5, 15 and 20 MeV. Cross sections will be determined to accuracies better than ±5% in the angle range from 45º to 135º relative to the gamma-ray beam axis and for an azimuthal angular acceptance of ±60°. This experiment will be the PhD thesis project two graduate students, Forrest Friesen at Duke University and another student from one of the TUNL institutions to be recruited. Also, the experiment will have a number of projects that are well suited for MS-degree students at North Carolina Central University and for advanced undergraduate students. In addition, the experimental techniques developed for these measurements and the apparatus can be adapted for other experiments at HIGS, e.g., measuring cross sections of (γ,p) and (γ,α) reactions on nuclei important for p-process nucleosynthesis.

P-03-13

Experiment: Measurement of neutron recoil polarization in low energy photodisintegration of deuterium

Spokesperson: Blaine Norum – UVa, ben@uva.edu

Hours: 240

Abstract

In 1934 J. Chadwick and M. Goldhaber stated [1], "Heavy hydrogen was chosen as the first to be examined, because the diplon has a small mass defect and also because it is the simplest of all nuclear systems and its properties are as important in nuclear theory as the hydrogen atom is in atomic theory." Obviously, a great deal of progress has been made since then, but it would be an exaggeration to say that the deuteron in particular and few nucleon systems in general are completely described theoretically. Starting with a few nucleon-nucleon potentials, it is possible to describe a range of data reasonably well, but with the advent of polarization measurements several unsolved mysteries have emerged. The polarization of the emerging neutron, P_y, in the reaction d (γ, ***n***) p, is a good example of such a mystery. Serious discrepancies between experiment and theory for even low incident photon energies exist. In particular, the most precise measurements of this reaction at energies below $E\gamma$ = 20 MeV, abruptly depart from theoretical predictions at around $E\gamma$ =10 − 12 MeV . In addition, the angular dependence of P_y has not been mapped well, with the available data being sparse and having large uncertainties. Nevertheless, a systematic discrepancy of the order of 15% between experiment and theory exists even for $E\gamma$ = 2.75MeV. Moreover, this discrepancy is observed at energies close to those of interest to Big Bang nucleosynthesis, hindering our understanding of processes in the early universe. We propose to precisely map P_y ($P^u{}_y$ herein), the neutron polarization produced by an unpolarized photon, and the associated beam (linear) polarization dependent quantity $P^l{}_y$ with beam energies around 12 MeV over a large range of polar angles, thus filling the gaps in existing data, as well as checking some of the recent theories being used to explain the aforementioned discrepancies. The experiment will utilize existing experimental equipment and components to be constructed, as well as the unique polarization and energy of the HIGS beam.

P-05-13

Experiment: High-resolution sub-barrier photofission measurements in actinides towards an improved understanding of the fission barrier structure

Spokesperson: Hugon Karwowski – TUNL, hugon@tunl.duke.edu

Hours: 100

Abstract

We propose to measure the cross section for photofission of ^{232}Th, ^{238}U, and ^{240}Pu at energies well below the maximum fission barrier of each isotope in an effort to establish more clearly an understanding of the potential energy surfaces that dene the fission barriers in the actinides. The characteristics of the fission barriers in actinides have been a subject of much debate in recent years, with experimental results indicating the existence of deep third minima and modern, self-consistent theoretical models failing to predict experimentally-observed features. The proposed exploration represents an expansion of an earlier, successful effort at HIGS which measured the sub-barrier cross section for ^{238}U(γ, f), carried out in part by several members of the team of the current proposal. This project will use a high-efficiency, well-characterized neutron detector to determine the sub-barrier photofission cross section of these isotopes between the energies of 3.6 MeV and 5.85 MeV. The asymmetrical bunch mode of HIGS will be used to obtain better than-2% energy resolution for E> 4.5 MeV in the cases of ^{238}U and ^{240}Pu, and for E> 5.2 MeV in the case of ^{232}Th. The obtained cross sections will provide information about the structure of the fission barriers that will hopefully serve to help reconcile the current disagreements between self consistent models of fission and experimental findings. The proposed project will offer TUNL students, at both the undergraduate and graduate level, an opportunity to be involved in a fission experiment at HIGS using several distinct detection methodologies. These students will gain valuable laboratory, analysis, and simulation experience throughout the project, in addition to exposure to a small, international research group with collaborators at Ludwig-Maximilians Universitat in Munich, Germany, and the Hungarian Academy of Sciences in Debrecen, Hungary, who bring with them many years of experience in fission research. This project will generate the experimental data leading to a Ph.D. thesis for a UNC graduate student at TUNL. This project is requesting 130 hours of HIGS beam time, and represents a continuation of an established, vibrant program of photofission measurements at HIGS

P-06-13

Experiment: Low-energy measurements of the $^{12}C(\alpha,\gamma)^{16}O$ reaction with a bubble chamber

Spokesperson: K. Ernst Rehm – ANL, rehm@anl.gov

Hours: 90

Abstract

After we have shown in a proof-of-principle experiment with the $^{19}F(\gamma,\alpha)^{15}N$ reaction that a bubble chamber can be used for quantitative measurements of very small cross sections we have started with the development of new bubble chamber using a superheated oxygen-containing liquid. A first 'engineering' run with N_2O was successfully performed in April, providing information about the so-called Harper factor which is needed to separate $^{16,18}O(\gamma,\alpha)$ from $^{14}N(\gamma,\pi)$ events. In this proposal we ask for a total of 8 days of beam time. The first four days will be used to measure the (γ,α) reactions on ^{18}O in the energy region $E\gamma$=7.5-10 MeV using enriched $N_2{}^{18}O$. Since the cross section for $^{18}O(\gamma,\alpha)$ is not well known in this region and is also the highest background for the planned $^{16}O(\gamma,\alpha)^{12}C$ experiment it is important to measure its energy dependence. This experiment will also provide information about the chemistry needed for the production of N_2O using relatively inexpensive enriched ^{18}O. If this test is successful we ask for an additional 4 days for a first measurement of the $^{16}O(\gamma,\alpha)^{12}C$ reaction in the energy range of 8.5-10 MeV.