Speaker : P. Mueller

Laser Trapping and Probing of Exotic Helium Isotopes

P. Mueller
Argonne National Laboratory

Abstract

We have succeeded in laser trapping and cooling of the exotic helium isotopes ^{6}He ($t_{1/2}$ = 0.8 sec) and ^{8}He ($t_{1/2}$ = 0.1 sec), and have performed precision laser spectroscopy on individual trapped atoms. Based on the atomic isotope shifts measured along the isotope chain ^{3}He - ^{4}He - ^{6}He - ^{8}He, and on the precise theory of the atomic structure of helium, the nuclear charge radii of ^{6}He and ^{8}He are determined for the first time in a method independent of nuclear models. The results are compared with the values predicted by a number of nuclear structure calculations and test their ability to characterize these neutron rich, loosely bound halo nuclei. The ^{6}He measurement was performed at ATLAS of Argonne, and the ^{8}He measurement at GANIL, France. This work was supported by the U.S. Department of Energy, Office of Nuclear Physics, under Contract No. DE-AC02-06CH11357.

Speaker : W. Noertershauser

Title:
Laser shed new light on Halos - Nuclear charge radii of 11Li and 11Be

Abstract:
High-resolution laser spectroscopy can be combined with accurate atomic physics calculations for the determination of nuclear charge radii of light elements. To obtain simultaneously the required high sensitivity and accuracy is the main challenge in these experiments and dedicated approaches have to be used for each individual element. I will give a short report on measurements of lithium isotopes including 11Li performed at TRIUMF in 2004 and then describe the experimental assembly that we are currently setting up for measurements of the isotope shifts of the beryllium isotopes Be-7,9,10,11.

Speaker : M. Smith

Mass Measurements of Halo Nuclei with the TITAN Penning Trap Spectrometer

Mathew Smith, TRIUMF/UBC

Since Hansen and Johnson's initial two body model of ^{11}Li it has been well know that low neutron binding energies are key to producing the halo phenomenon. These binding energies can be found experimentally through precision mass measurements. Further, even more stringent values of masses are required to aid in the interpretation of other experimental results, such as measurements of isotope shifts and invariant mass spectrometry. To this end a series of measurements are now underway to obtain the masses of a number of halo nuclei using the TITAN Penning trap spectrometer.

In its final configuration the TITAN Penning trap spectrometer will use the unique combination of a gas-filled Radio-Frequency Quadrupole (RFQ), Electron Beam Ion Trap (EBIT) and precision Penning trap to make high accuracy, $\delta m/m \approx 1\text{x}10^{-9}$, mass measurements on highly charged ions. However, the TITAN experiment also allows for injection of singly charged ions, extracted from the RFQ, directly into the Penning trap. This uniquely enables measurements on very short lived isotopes, $t_{1/2} < 10$ ms.

Results will be presented from the recent measurements of the four neutron halo nucleus ^{8}He and the archetypical two neutron halo ^{11}Li with the TITAN spectrometer. The measurement of ^{11}Li sets a new record for the shortest lived isotope ever measured using Penning trap mass spectrometry, $t_{1/2}$ = 8.8 ms. This breakthrough development has pushed the limits in the half-lives accessible to Penning trap mass spectrometry down by almost an order of magnitude. Programs to further study the halo nuclei $^{6,8}He$, $^{12,14}Be$ and $^{17,19}N$ are now planned for the near future.

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We have succeeded in laser trapping and cooling of the exotic helium isotopes ^{6}He ($t_{1/2}$ = 0.8 sec) and ^{8}He ($t_{1/2}$ = 0.1 sec), and have performed precision laser spectroscopy on individual trapped atoms. Based on the atomic isotope shifts measured along the isotope chain ^{3}He - ^{4}He - ^{6}He - ^{8}He, and on the precise theory of the atomic structure of helium, the nuclear charge radii of ^{6}He and ^{8}He are determined for the first time in a method independent of nuclear models. The results are compared with the values predicted by a number of nuclear structure calculations and test their ability to characterize these neutron rich, loosely bound halo nuclei. The ^{6}He measurement was performed at ATLAS of Argonne, and the ^{8}He measurement at GANIL, France. This work was supported by the U.S. Department of Energy, Office of Nuclear Physics, under Contract No. DE-AC02-06CH11357.

Structure of Exotic Nuclei Probed by Spin-Polarized Radioactive Beams*

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We have proposed a unique method to investigate the structures of the exotic nuclei by using spin-polarized unstable nuclear beams[1]. The essence of the method is the use of spatially asymmetric decay of β-transition from a spin-polarized nucleus. Since the β-decay asymmetry strongly depends on the spins and parities of the initial and final states, we can assign the spin-parity of the final states daughter by observing the asymmetry in coincidence with the successive decays to the β-decay.

The first application was successfully made[2] using the highly polarized ^{11}Li beam at TRIUMF , where highly polarized radioactive nuclear beams were available by the collinear optical pumping for the fast neutral alkali beam. The excited states in the light neutron-rich nucleus ^{11}Be have been studied through the β-delayed neutron- and γ-decays from polarized ^{11}Li$_{g.s.}$. The level scheme and decay scheme of the excited states in ^{11}Be were established from the β-γ, β-neutron and β-neutron-γ coincidences, and the spins and parities of 6 levels in ^{11}Be were firmly assigned for the first time[2]. The detailed information on excitation energy, spin-parity, β-decay intensity, neutron-decay path, and spectroscopic factors of the neutron decay enables us to test stringently theoretical predictions. It is found that the excess neutrons in ^{11}Be are not in the *p*-orbit as predicted by the conventional shell model but in the *s*-orbit. Some of the levels show good accord with the theoretical prediction by the Anti-symmetrized Molecular Dynamics[2]. It is concluded that various types of the cluster states exist in ^{11}Be[2].

Another experiments[3] with polarized ^{28,29,30,31,32}Na isotopes are ongoing at TRIUMF to investigate the structure of neutron-rich ^{28,29,30,31,32}Mg isotopes with the neutron number *N*~20 (nuclei of the "island of inversion"), respectively. The most of spins and parities of the excited states in these nuclei have not been assigned yet. Our method will establish firm assignments.

* The work has been performed in collaboration with Y. Hirayama, H. Izumi, H. Hatakeyama, M. Yagi, H. Yano,
H. Miyatake, C.D.P. Levy, K.P. Jackson. M. Pearson, K. Kawai, Y. Akasaka, A, Odahara, T. Fukuchi, T. Suzuki, K. Tajiri,
K. Kura, T. Hori, T. Masue, M. Kazato, M. Suga and A. Takashima.

1) H. Miyatake *et al*.: Phys. Rev. C **67** (2003) 014306.
2) Y. Hirayama *et al*.: Phys. Lett. B **611** (2005) 239.
3) T. Shimoda a *et al*.: TRIUMF experiment proposal S1114 (2006).

Speaker : R. Raabe

Title :
Deuteron emission from 11Li: decay of the halo

Abstract :

We studied the deuteron-emission channel in the beta decay of the short-living halo nucleus 11Li using the post-accelerated beam produced at the ISAC facility in TRIUMF. After implantation in a finely segmented silicon detector, the events of interest were identified through time and position correlations between the implantated nuclei and the subsequent decays. The results support the picture of the decay taking place essentially in the halo of 11Li and proceeding directly to the 9Li+d continuum.

Speaker : M. Mark

Title :
Exploring Efimov physics in ultracold atomic and molecular quantum gases

Abstract:
I will report on our experiments with ultracold, optically trapped cesium atomic and molecular gases to investigate Efimov's prediction of the existence of a universal set of weakly bound trimer states. Cesium atoms offer the possibility to magnetically tune the scattering length.
By using Feshbach resonances we can efficiently produce ultracold trapped dimer molecules. In atom-atom-atom [1] as well as atom-dimer [2] collisional studies we observe resonantly enhanced loss rates as a function of the scattering length. These loss resonances indicate the existence of an Efimov trimer state. We have recently set-up the technique of resonantly modulated magnetic field spectroscopy which in the future might allow to directly observe Efimov states.

[1] T. Kraemer, M. Mark, P. Waldburger, J. G. Danzl, C. Chin, B. Engeser, A. D. Lange, K. Pilch, A. Jaakkola, H.-C. Naegerl and R. Grimm, Nature 440, 315 (2006).
[2] S. Knoop, F. Ferlaino, M. Mark, M. Berninger, H. Schoebel, H.-C. Naegerl, and R. Grimm, manuscript in preparation (2008).

Speaker : T. Myo

Title
Role of the explicit tensor correlation in neutron halo nuclei

Abstract

We discuss the structures of He and Li isotopes with the tensor correlation. Based on the core+n+n model including the tensor correlation in core part, we investigate the disappearance of the N=8 shell gap in halo nuclei 11Li and the neighboring nuclei. It is shown that the Pauli-blocking effects caused by the tensor and pairing correlation of 9Li core plays an important role to enhance the s^2 probability as 50% in 11Li. Our model further explains the Coulomb breakup reaction, charge radius and Q-moment of 11Li and also the inversion phenomena of 10Li.

Speaker : Y. Ogawa

Title :
The role of pions on nuclei and observable characters based on the relativistic chiral mean field model

Abstract :

We construct a relativistic framework which takes into the pionic correlation (iterated one-pion exchange) account seriously on the basis of chiral mean field model. The tensor part is very strong at medium interaction range (around 1 fm), and produces large attractive force for the triplet-even state. The central part produces the large repulsive force for the triplet-odd state.

The pseudoscalar nature of pions introduces the high momentum correlations in the interaction between nucleons. For explicit introduction of pions, the framework has to possess a thorough model space in order to describe this important nature.

Although our framework is already far beyond mean field theory, we will show ideas to make our framework (relativistic chiral mean field with projection) easy to use for serious description of pionic correlation and its essential points.
We will also discuss the role of pions on finite nuclei and its observable characters.

Speaker : A. Wuosmaa

Ttile : Transfer reactions with exotic beams at ATLAS – current status and future prospects

Abstract :

Nucleon transfer reactions are again important central tools in the study of the structure of exotic nuclei. Nucleon stripping and pickup reactions are particularly important to the understanding of single-particle states in exotic nuclei, and can be used to test modern theoretical nuclear-structure models that predict spins, parities, and spectroscopic factors for states in exotic light nuclei. This benefit comes at a cost – the most interesting experiments utilize radioactive beams and are carried out in inverse kinematics, thereby adding to the technical complexity of the measurements. I will review some examples of transfer reactions with light exotic nuclei carried out at the ATLAS facility at Argonne National Laboratory, and discuss a coming initiative – HELIOS – that may address some of the experimental difficulties encountered in these studies.

Speaker : C. Scheidenberger

Present and future opportunities for the study of skin- and halo-nuclei at GSI and FAIR

Speaker : T. Nakamura

Title : Low-Lying Excited States of Halo Nuclei

One of the unique features of halo nuclei is that the continuum just above the neutron-decay threshold plays an important role since the separation energy is very small. We present recent spectroscopic studies of continuum and resonance states of halo nuclei 11Li, 14Be and 19C.For 11Li, we have observed a strong E1 strength at Erel~0.3MeV in the Coulomb breakup[1]. For 14Be, we have applied the (p,p') and (12C,12C') reactions for exciting the first 2+ state[2]. We have also studied the 13Be resonances which are produced in the breakup of 14Be. For 19C, we have applied the (p,p') reaction to observe the unbound state[3]. By showing these results, we discuss the characteristic features of excitation properties of halo nuclei.

[1] T.Nakamura et al., Phys. Rev. Lett. 96, 252502 (2006).
[2] T.Sugimoto, T.Nakamura et al., Phys. Lett. B 654, 160 (2007).
[3] Y.Satou, T.Nakamura et al., Phys. Lett. B, in press.