



National Nuclear Physics Summer School
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Poster Session

Buuck, Micah

**“A Single-Site Pulse Basis Technique for Multi-Site Event Tagging with
the MAJORANA DEMONSTRATOR”**

Abstract:

Analysis-based background suppression techniques are routinely employed to maximize the sensitivity of experiments designed to observe extremely rare processes, such as neutrinoless double beta ($0\nu\beta\beta$) decay. The Majorana collaboration is implementing a Pulse Shape Analysis algorithm, which allows single-site events such as $0\nu\beta\beta$ decay to be distinguished from multi-site background events in germanium detectors.

The algorithm is based on the event-by-event χ^2 fitting of experimental signals to a basis data set of unique single-site pulse shapes generated with a novel algorithm developed by members of the collaboration.

Preliminary studies have suggested that the technique is able to successfully identify and reject up to 99% of multi-site events in the single escape peak associated with the gamma decay of ^{208}Tl , while maintaining a survival probability of up to 98% for neutrinoless double-beta-decay-like double escape peak events. Here we present results of the application of this technique to data.

Cai, Yiming

"Sign problem in QCD with a theta term ---- subtleties with the infinite volume limit"

Abstract:

QCD and related gauge theories have a sign problem when a theta -term is included. The sign problem inhibits our ability to use numerical lattice method to explore many significant problems in QCD. Some subtle effects arise in the infinite volume limit which has interplay with the sign problem. This poster will illustrate these effects.

Poster 1

"Scaling and Correlations: two-nucleon knockout, two-body momentum distributions, and contact interaction"

Abstract:

Two-nucleon short range correlations (SRC) in nuclei account for 25% of the nucleons in the nucleus and for all nucleons with momentum above the Fermi momentum. From a theoretical standpoint, they constitute a large correction to mean-field theories. The characterization of SRCs is an essential task in nuclear physics. To this end, theoretical progress has been made in the last few years with calculations of two-body momentum distributions. Similarly, experimental progress has come through hard two-body-knockout reactions and inclusive electron scattering measurements. The analysis presented sets to study the connection between the mentioned theoretical and experimental tools. To this end we: (1) Construct a simple model of the nucleus using Monte Carlo simulations to generate two-body momentum distributions that yield general characteristics of SRC pairs. (2) Use this information in order to analyze more realistic momentum distributions generated from variational Monte Carlo calculations (VMC) using the Argonne v18 two-nucleon and Urbana X three-nucleon potentials (AV18+UX). (3) Contrast results obtained from these calculations to measurements of the $4\text{He}(e,e'pp)$ and $4\text{He}(e,e'pn)$ reactions performed at Jefferson Laboratory. From this analysis we conclude that in order to study SRC pairs using two-body momentum distributions one should focus on a region of low center-of-mass momentum, to avoid contaminations from un-correlated nucleons. In this region, consistent with experimental data, scaling of momentum distributions above the Fermi momentum is verified. Finally, consistency between theoretical calculations and experimental measurements is found.

Poster 2

" $A = 3$ Nuclei: A Lab for Energy Sharing in Asymmetric Systems"

Abstract:

In non-interacting Fermi systems with imbalanced number of two different Fermions, the average momentum per fermion is higher for the majority. Adding a strong short-range interaction between different fermions may invert the momentum sharing of the two components, making the minority move faster on average than the majority. This feature is due to the high momentum distribution being dominated by short distance pairs of different type Fermions. It is a common behavior that applies to systems ranging from ultra-cold atoms at neV energies to nucleons with MeV energies. In nuclei the nucleon-nucleon tensor force makes the neutron-proton short range correlated pair (np-SRC) the dominant component contributing to the high momentum of nucleons. In light neutron-rich nuclei such as 3H , the average momentum of a proton should be higher than that of a neutron. In 3He the average momentum of the neutron should exceed that of the protons. We plan to test the above prediction experimentally by probing both the majority and minority nucleon momentum distributions of asymmetric $A = 3$ nuclei. We will do this by measuring the quasi-elastic $3\text{H}(e,e'p)$ and $3\text{He}(e,e'p)$ reactions in high- Q^2 , $x_B > 1$ kinematics where the effects of FSI are minimized. The use of mirror nuclei allows using probing the properties of the proton in one nucleus and learning about the properties of the neutron in the other. The experiment will run in 2017 at Hall-A of Jefferson-Lab, using an incoming 4.3 GeV electron beam and High Resolution Spectrometers (HRS) to detect scattered electrons and knockout protons. We will extract reduced cross-sections and cross-sections which will be used as a direct benchmark to detailed nuclear calculations in a regime they have not been tested in before.

Dongwi, Dongwi H.

"Search for New Physics with Experiment E36 at J-PARC"
For the TREK Collaboration

Abstract:

We are potentially standing at the precipice in searching for New Physics (NP) beyond the Standard Model (SM) by performing a precision test of lepton universality – a basic assumption of the SM that assigns an identical coupling constant to e , μ and τ . The E36 experiment conducted at J-PARC in Japan will test lepton universality in the $R_K = \Gamma(K_{e2})/\Gamma(K_{\mu2})$ ratio. In the SM, the ratio of leptonic K^+ decays is highly precise with an uncertainty of $\Delta R_K/R_K = 4 \cdot 10^{-4}$. Any observed deviation from the SM prediction would break the universality of the lepton couplings and provide a clear indication of NP beyond the SM. Although a successful description of the basic building blocks of matter, the SM is incomplete in falling short to describe dark matter, baryogenesis, neutrino masses and much more. The E36 detector apparatus allows sensitivity to search for light $U(1)$ gauge bosons and sterile neutrinos below $300 \text{ MeV}/c^2$, which could be associated with dark matter or explain established muon-related anomalies such as the muon $g-2$ value, and perhaps the proton radius puzzle. A scintillating fiber target was used to stop a beam of up to 1.2 Million K^+ per spill. The K^+ products were detected with a large-acceptance toroidal spectrometer capable of tracking charged particles with high resolution, combined with a CsI(Tl) photon calorimeter with large solid angle covering 70% of 4π and particle identification systems. The status of the data analysis will be presented.

This work has been supported by DOE awards DE-SC0003884 and DE-SC0013941 in the US, NSERC in Canada, and Kaken-hi in Japan.

Hardin, John M.

"A Focusing DIRC Detector for GlueX"

Abstract:

The GlueX experiment will soon provide unprecedented sensitivity to light-quark exotic meson states. The detector is installed in Hall D at Jefferson Lab, and has begun taking calibration data. A vital upgrade to the particle identification system is currently being developed that makes use of the BaBar DIRC bars. This poster will present the current status of the GlueX focusing DIRC project, including the design and prototyping of a novel focusing system and development of reconstruction algorithms.

Jackura, Andrew

"Partial Wave Analysis of 3π Systems"

Abstract:

We present some results on the analysis of 3π resonances from peripheral scattering of pions off of nuclear targets. The analysis is motivated by the recent release of the largest data set on diffractively produced three pions by the COMPASS collaboration. The model emphasizes the 3π production process and their final state interactions which satisfy S-matrix principles. We apply our model to fit partial wave

intensities and relative phases from COMPASS in the $J^{PC} = 2^{-+}$ sector and search for resonances.

McDonald, Scott 1 Chun Shen,1 Sangyong Jeon,1 and Charles Gale1

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"Hadronic Flow Predictions and Postdictions for Run 2 at the
LHC Using IPGlasma Initial Conditions"

Abstract:

Using a new formulation of IPGlasma in conjunction with MUSIC+UrQMD, we confront new flow data recently published by the ALICE collaboration at 5.02 TeV [1], and make predictions for observables for which data has yet to be published. We achieve excellent agreement with experimental data for hadronic flow observables at $\sqrt{S_{NN}} = 2.76$ as well for quantities already measured 5.02 TeV. Observables for which data has yet to be published are predicted at the higher LHC energy. Such quantities include identified particle $\langle p_T \rangle$, event-by-event v_n distributions, identified particle integrated v_n , differential charged hadron v_n , as well as two- and three-plane v_n correlations. The role of QGP transport coefficients, particularly shear and bulk viscosities, will be emphasized.

[1] A. Collaboration, (2016), 10.1103/PhysRevLett.116.132302, arXiv:1602.01119.

Mulligan, James

"Probing the Quark-Gluon Plasma with Jets at ALICE"

Abstract:

Heavy ion collisions at sufficiently high energies produce a hot QCD medium with delocalized quarks and gluons, known as the quark-gluon plasma (QGP). The ALICE detector is one of four major experiments at the Large Hadron Collider, and its main purpose is to study the behavior of this QCD system. One method to study the QGP is to measure the modification of QCD jets passing through the medium by comparing various jet observables in heavy ion collisions to those in pp collisions. I present an introduction to these topics, and outline a di-jet asymmetry analysis I am in the early stages of performing.

Papadopoulou, Afroditi

"Correlated Fermi Gas Model (CFG)"

Abstract:

The analysis of neutrino oscillation experiment rely on the ability to reconstruct the incoming neutrino energy based on the measured final state particles. This requires a detailed description the structure of nuclei and the way neutrinos interact with the nucleons in the nucleus. Results from high-energy proton and electron scattering experiments, which show that short-range interactions between the fermions form correlated, high-momentum ($k > k_F$), neutron-proton pairs. These pairs account for 20% – 25% of the nucleons in the nucleus and are not been taking into account in standard neutrino interaction event generators.

Using experimental data obtained from inclusive and exclusive electron scattering experiments we construct the Correlated Fermi-Gas (CFG) model - a data driven analytical model for the nuclear momentum distribution in symmetric and asymmetric nuclei. In this poster I will present the CFG model, the data used to constrain its free parameters, and our plans to incorporate it into the GINIE neutrino-nucleus interaction event generator.

Rahman, Sakib

Abstract:

MOLLER Detector Simulations and Background Stud-ies SAKIB RAHMAN, University of Manitoba — The MOLLER ex-periment proposes to measure the parity-violating asymmetry A_{PV} in electron-electron (Møller) scattering.

$$A_{PV} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

where σ_+ and σ_- are the cross-sections for scattered electrons with positive and negative helicity respectively. In the experiment, an 11 GeV beam of longitudinally polarized electrons is incident on a liquid hydrogen target. The yields in each helicity state are measured by an array of 224 integrating quartz detectors 28 meters downstream from the target position. A spectrometer consisting of two resistive toroidal magnets and a system of collimators provides kinematic separation and shielding from backgrounds. The yields need to be corrected for helicity-correlated beam properties and background asymmetries to achieve high precision. The goal of this work is to optimize the signal-to-background contributions at the detector plane, including both the dilution and asymmetry from different backgrounds by minimizing and understanding their sources and the relative responses of the detectors. This poster discusses the status of background studies performed with the Geant 4 simulation toolkit and the development of a parametrized detector geometry in the simulation.

Segarra, Efrain Patrick

"The OLIVIA experiment – A 'Trapless' beta decay study"

Abstract:

High precision measurements of nuclear decays are one of the most precise tools for probing physics beyond the standard model. High precision measurements at low energies indirectly probe physics at very high energies, rivaling that of the largest accelerators, while still remaining a relatively inexpensive research program.

The OLIVIA experiment is new experiment that will perform a kinematically complete measurement of ^8Li beta decay in 3D. While most similar measurements use optical traps, OLIVIA is based on a TPC surrounded by electron detectors. The proposed setup therefore does not require trapping the ^8Li ions which significantly simplifies the measurement and increases its statistical accuracy. The proposed experimental setup, rate estimates, and feasibility measurements with the TPC will be presented, along with the sensitivity to the neutrino-beta correlation coefficient and the capabilities of the experiment to constrain Tensor currents in electroweak theory.

Singh, Jagjit

"Pairing in the continuum: Electric multipole response of the halo nucleus ^6He "

Abstract:

The role of different continuum components in the weakly-bound nucleus ^6He is studied by coupling unbound spd-waves of ^5He by means of simple pairing contact-delta interaction. The results of our previous investigations in a model space containing only p-waves, showed the collective nature of the ground state and allowed the calculation of the electric quadrupole transitions. We extend this simple model by including also sd-continuum neutron states and we investigate the electric monopole, dipole and octupole response of the system for transitions to the continuum, discussing the contribution of different configurations.

Škerbiš, Urša

"Scattering of Particles with Spin on the Lattice"

Abstract:

All stable hadrons under strong interactions have already been studied in lattice QCD. Previous studies have discussed scattering of hadrons without spin. Almost no work has been done in lattice QCD for scattering of particles with spin. On this poster we give a short introduction to the scattering of particles with spin. Appropriate creation and annihilation operators for scattering systems are required in these simulations. Analytical derivations in different methods are described and some of our results presented.

Wagman, Michael

"Neutron Antineutron Operator Renormalization"

Abstract:

The observed matter-antimatter asymmetry of the universe is an outstanding mystery of physics that cannot be explained within the Standard Model. Many beyond the Standard Model (BSM) explanations have been proposed, and experimental data is needed to constrain the wide theory space of BSM models. Neutron-antineutron oscillations are predicted to be a signature of some BSM baryogenesis models and can be cleanly probed by low-energy experiments. Connecting experimental data on neutron-antineutron transition rates to fundamental BSM theory parameters requires QCD matrix elements of six-quark operators effectively parameterizing BSM physics at low energies. I present recent work on the renormalization group analysis necessary to connect BSM scales to computationally accessible lattice QCD scales and ongoing lattice QCD efforts to reliably determine neutron-antineutron QCD matrix elements.

Xiong, Zewei

"Oscillations of Solar High-Energy Neutrinos"

Abstract:

GeV neutrinos can be produced by cosmic rays interacting with the solar atmosphere and by annihilation of dark matter particles accumulated inside solar interior.

We study how 3-flavor oscillations affect the detection probabilities of these neutrinos, exploring the yet-unknown neutrino mass hierarchy and CP violation phase in the mixing matrix.

We also compare analytic approximations with numerical results to understand 3-flavor oscillations in matter with varying density and their effects on solar high-energy neutrinos.

Yan, Xinshuai

"Discrete-symmetry transformations of B-L violating operators"

Abstract:

We consider the transformation properties of fermions under the discrete symmetries CPT, CP, and C in the presence of B – L violation. We thus generalize the analysis of the known properties of Majorana neutrinos, probed via neutrinoless double beta decay, to include the case of Dirac fermions with B – L violation, which can be probed via neutron-antineutron oscillations. We show that the resulting CPT phase has implications for the interplay of neutron-antineutron oscillations with external fields and sources.

Yao, Xiaojun

"Static and Dynamic Screening Effects on the Resonant Alpha-Alpha Scattering in a QED Plasma"

Abstract:

The plasma screening effect on the low-energy scattering between alpha particles (Helium 4) is studied by using the pionless effective field theory and thermal field theory. It is known that in vacuum a resonance lies at the center-of-mass energy 91.84 keV with a width 5.57 eV, identified as the ground state of Beryllium 8. It is found that the static (Debye) screening decreases the resonance energy and width. A bound state starts to form when the Debye mass is larger than 0.3 MeV. However, when the dynamic screening effect is included, which results in an imaginary potential (damping rate), both the resonance energy and width increase with the plasma temperature. Then the screening effect on the thermal nuclear scattering rate is studied and found to suppress the rate by more than 800 times when the temperature is 10 keV around. These screening effects may have implications on the rates of nuclear reactions with a resonance in the thermal domain, many of which are of great interest in cosmology and astrophysics.

Zhao, Yong

"Proton Spin Structure from Large-Momentum Effective Theory"

Abstract:

We propose a method to calculate the partonic contributions to the proton spin. This method, named large-momentum effective theory, allows us to extract the parton spin and orbital angular momentum from certain nucleon matrix elements that can be directly calculated in lattice QCD.