Characterizing Piezoelectric Tuners for Microphonics Compensation.

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Microphonics arise when external noise sources excite various mechanical modes within an accelerator’s superconducting radio frequency (SRF) cavities. Reliable tuning systems are needed to counteract the detuning of cavity resonance frequencies caused by these mechanical vibrations. Cavity detuning induces errors in the amplitude and phase of the accelerating gradient, which must be kept stable for proper electron beam acceleration. The SRF cavities being installed as part of Jefferson Lab’s 12 GeV upgrade have an increased quality factor, resulting in a correspondingly decreased bandwidth. This property causes them to be particularly susceptible to microphonics detuning, raising the importance of corrective compensation. Compensation can be achieved by the low-level radio-frequency (LLRF) control system, but this method requires employment of RF power, which is limited in supply. The objective of this study is to investigate an alternative compensation method using piezoelectric tuners to mechanically damp microphonics in SRF cavities. Measurements were taken in the CEBAF tunnel and the cryomodule test facility (CMTF) to characterize the background microphonics spectrum of each environment and the frequency response of the piezo tuner. A mathematical model, coded in Matlab, was used to reproduce and analyze the frequency response between the piezo tuner and the cavity detuning (amplitude and phase). Analysis of the mathematical model revealed that the system’s previously mysterious phase behavior can be attributed to a combination of either positive or negative transient detuning responses from excitation of the cavity’s different mechanical modes. Both measurement and simulation aided in the development of a more detailed understanding of the microphonics spectrum and the tuner-cavity system. Mechanical compensation based upon this characterization is a compelling solution for tuning cavities in continuous wave (CW) mode. The next step is to use a negative feedback signal representing the cavity’s detuning angle (from the LLRF chassis) to drive the piezo actuator, potentially reducing the overall detuning amplitude. The ability to use piezoelectric components to tune the SRF cavities would allow RF power to be utilized more efficiently to create high accelerating gradients in the future.
ABSTRACT

Impact of Parton Distribution Function Uncertainties on Cross Sections and Asymmetries.
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Hadrons are made out of quarks and gluons, collectively termed partons, which are held together in the hadron by the strong nuclear force. Parton Distribution Functions (PDFs) quantify the likelihood of finding a parton with a fraction $x$ of the hadron's momentum, and combinations of these PDFs form structure functions that characterize the internal structure of the hadron. These structure functions are usually examined in the Bjorken limit, where the ratio of the mass of the hadron ($M$) to that of the scattering photon ($Q^2$) is zero; however, in practical experiments, where $Q^2$ is finite, so-called Target Mass Corrections (TMCs) must be applied. Since the PDFs are derived from data, including those for nuclear targets, nuclear corrections need to be applied when extracting PDFs. There are several theoretical formulations of both TMCs and nuclear corrections, creating a range of possible structure functions and PDFs; this project compares the predictions of the different structure functions using the most recent PDF fits from Jefferson Lab. The corrected PDFs were analyzed by direct comparison with each other and by examining the uncertainties produced in experimental predictions. Specifically, parity-violating deep inelastic scattering (PVDIS) and $W$ and $Z$ boson production were studied. It was found that both types of corrections were most influential at low values of $Q^2$ and when the interacting parton possessed a large fraction ($x>0.7$) of the hadron's momentum. Asymmetries between polarized electrons in PVDIS were studied with respect to TMCs, with deviations away from uncorrected predictions quantified. The dependence of $W$ and $Z$ boson cross sections on nuclear corrected PDFs in proton-proton collisions was studied, where the $W$ boson was found to have strong sensitivity to uncertainties in the down quark distribution at large $x$. Future experiments in PVDIS have been proposed to determine the PDFs at large $x$, and this paper shows how sensitive those future experiments will be to the non-zero mass of the target hadrons. In addition, the $W$ and $Z$ boson predictions extend to the theorized $W'$ and $Z'$ bosons which, could be detected in future experiments at colliders such as the Large Hadron Collider.
ABSTRACT

Improvements to the Compton Polarimeter in Hall C. BRANDON S. CAVNESS (Angelo State University, San Angelo, TX 76904) DAVID GASKELL (Thomas Jefferson National Accelerator Facility, Newport News, VA).

The Thomas Jefferson National Accelerator Facility (Jefferson Lab), in Newport News, Virginia, uses a polarized beam of electrons to perform research on the substructure of nuclei and nucleons. Polarized electrons are ones with their spins aligned in the same direction. Hall C at Jefferson Lab uses a relatively new Compton polarimeter to continuously measure the polarization of the electron beam delivered by the Continuous Electron Beam Accelerator Facility (CEBAF) accelerator into Hall C. The Compton polarimeter determines beam polarization by colliding a high-power laser with the electron beam and measuring the scattered photons and electrons. Electrons preferentially scatter off photons spinning in the same direction versus those with opposite spin. The Compton polarimeter utilizes this asymmetry of Compton scattering rates to measure polarization to (+/-)1% every few hours. For an accurate measurement, the laser polarization and the position of the scattered photon cone must be well known. The focus of this project was to expand the instrumentation used to monitor and control the Compton polarimeter with the intent of improving the electron beam polarization measurement. The first task was to develop a “non-expert” utility for measuring laser polarization and incorporate it into the existing controls program. Furthermore, scintillator detectors were built, attached to motorized mounts that allow accurate movement horizontally and vertically, and software was written to control them remotely. These will be used to determine the position of the scattered photon cone for accurately determining the ideal photon detector location. The modifications to the LabVIEW program have improved the controls program functionality and will allow for a more accurate measurement of the laser polarization. The scintillator detectors remote control mechanism has been successfully developed, and the detectors have been shown to produce expected signals during testing. The individual components of the system are all working as intended, but the system as a whole will not be tested until beam operations resume this fall. An improved measurement of the electron beam polarization will reduce the uncertainty of future experiments performed in Hall C.
ABSTRACT


The Medium Energy Electron Ion Collider (MEIC) at Thomas Jefferson National Accelerator Facility (JLab) has been envisioned as a future high energy particle accelerator beyond the 12 GeV upgrade of the existing Continuous Electron Beam Accelerator Facility (CEBAF). The electron cloud effect (ECE), which is a result of beam-induced multipacting, can cause beam instability, increased heat load, and increased gas pressure in the beam chamber. Therefore, it is important to understand this effect for the MEIC. The goal of this project is to study how the electron cloud evolves and to explore the effects of different parameters on the electron cloud in the MEIC using computer simulation. Specifically, the parameters studied were the repetition rate, pipe radius, magnitude of a uniform magnetic field for a dipole magnet, intensity, bunch spacing, and gas pressure. Various computer programs have been written to simulate the multipacting process. These computer programs were previously studied at the European Organization for Nuclear Research (CERN). Ultimately, the program ECloud was chosen for the simulations. It is shown that the electron cloud line density is directly related to repetition rate, intensity, and gas pressure and is inversely related to pipe radius. The electron cloud line density has a linear relationship with gas pressure and nonlinear relationships with the other parameters. Lastly, the relationship between the electron cloud line density and bunch spacing is complex. Long bunch spacing (greater than 1.5 m) allows for saturation to occur and the electron cloud line density reaches equilibrium. With short bunch spacing, the electron cloud grows exponentially, peaks at a time determined by the bunch spacing and number of bunches in the train, and then falls off exponentially. The next step is to use data from this project to study beam instability in the MEIC due to electron cloud build up.
A Study of Quasi- Elastic Electron Scattering from the Deuteron.  
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The scattering of electrons from nuclear targets is one of the best tools available to physicists to look inside the nucleons that form our world. By bombarding atoms with electrons and measuring the probability of interaction (nuclear cross section), one can calculate the distribution of the quarks and gluons inside the nucleons. While this is a straightforward process for a proton, the desire to explore the structure of the neutron necessitates the use of the deuteron and other light nuclei as targets. However, in the case of a deuteron target, for a certain range of kinematic variables, the electron scattering results in a nucleon inside the deuteron getting knocked out intact, producing a final state with two nucleons. This process is known as quasi-elastic electron scattering. The focus of this project was to develop and test new theoretical models to predict the cross section for quasi-elastic electron-deuteron scattering, while allowing for the struck nucleon to be off-mass-shell, or in other words, bound. This was done by treating the interaction as the exchange of a single virtual photon between the electron and one nucleon, while the other nucleon was considered a spectator, playing no part in the process. Based on this assumption, previously derived results for deep inelastic electron scattering were applied to the quasi-elastic case and used to obtain equations for the deuteron cross section. These equations were then used to compare the theoretical model with existing experimental data. It was found that the computed cross section values had a very good agreement with the experimental data, whereas the off-mass-shell corrections made a negligible contribution to the results. Based on this, it could be concluded that the theoretical model used is an accurate description of quasi- elastic scattering, and that more complicated interactions between the nucleons, such as meson exchange currents or final state interactions, do not play a significant role in the process. The comparison of the calculations with the collected data can also be used to gain information about the momentum distribution of the nucleons inside the deuteron, especially in the relatively unexplored region where the momentum of the nucleons is large.
The Polarized Electrons for Polarized Positrons (PEPPo) experiment is a proof-of-principle experiment designed to produce and then measure polarized positrons at the Continuous Electron Beam Accelerator Facility (CEBAF) located at the Thomas Jefferson National Accelerator Facility (JLab). A highly spin-polarized electron beam will strike a thin tungsten foil and produce positrons through the two-step process of polarized Bremsstrahlung and pair creation. The polarization of the collected positrons will be analyzed in another two-step process, firstly Bremsstrahlung to produce polarized gamma rays and then Compton scattering of the gamma rays with a thick polarized iron target. The goal of this project is to model and measure the magnetic properties of the iron target used in the PEPPo experiment, which is immersed in a powerful magnetic field at the core of a solenoid magnet. To model the nature of the magnet, the finite element electromagnetic solver code Poisson was used, and implemented for the configurations planned for the experiment. Because the analyzing magnet is operated in saturation mode, realistic curves relating the magnetic induction (H) to the magnetic field (B) are considered. The model of the magnet could then be compared against measurements of the magnetic flux passing through the iron core as determined by measuring the electromotive force (EMF) of pick-up coils encompassing the iron core. By comparing the model to the measured EMF, it was found that the model predicted EMF’s that did not closely match the experimental values. While the model predicted the general behavior of the EMF, the experimental values where several times larger than the predicted EMF’s. This would indicate that a more thorough test, such as the measurement of the external magnetic field, is needed to further evaluate the model. While results from the measurement of the external magnetic field could dramatically change the characteristics of the model, it was impossible to take them due to time constraints. With the knowledge of the external magnetic field, it would be possible to improve the model, so that the magnetic field within the iron core may be precisely known. With a precise model of the iron core, it would be possible to use the magnetic polarization in the calculation of the transmission rates in the Compton scattering of photons.
In the proposed experiment Gep(5), the structure of the proton will be studied through elastic scattering of electrons off of stationary protons. This allows for the measurement of the proton elastic form factors, which are functions of the electron momentum transfer, $Q^2$. These form factors are fundamental constants of the nucleon and describe the internal structure of the proton. In order to ensure that the scattering events are elastic the proton angle and energy will be measured with a magnetic spectrometer, and the electron angle and energy will be measured with a lead glass calorimeter, called BigCal. An aluminum shield is typically placed front of BigCal to shield the calorimeter from unwanted radiation, but this is also causing a loss of resolution in the measured energy. A simulation was carried out to determine whether replacing the shield with radiation hardened lead glass would significantly improve the resolution of the calorimeter. A Monte Carlo simulation was made to examine the event of an electron striking the shield and BigCal. The simulation was run with the aluminum shield in place, and then again with the new radiation hard lead glass shield. With the new shield, the energy lost in the electron was added to the energy measured in BigCal in order to obtain the total energy. Comparing the new total energy to the original value in BigCal it was found that the resolution improved by a factor of 2 with the lead glass shield. This result confirms that the energy lost in the shielding material is directly related to the energy of the scattered electron. This improvement in resolution will be useful in isolating elastic events, and analyzing the proton form factors.
Abstract

The genetic algorithm is a relatively new optimization tool that uses the ideas implemented in biological processes of evolution to arrive at the best solution for a given optimization problem. The algorithm works especially well for problems with a big quantity of local optima and has been shown to provide good results in a short amount of time for optimization of accelerator processes such as beam-beam collision. The success of genetic algorithm motivates an attempt to implement it for another problem – in the case of this project, minimizing the electron beam coupling, which is essential to prevent degradation of the beam quality. The genetic algorithm was set to work with electron beam code Elegant, first for a model case to work out the best parameters and strategy, and then for a more realistic case. The parameters studied included a number of individuals per generation and variables that control the size of mutation and recombination. It was shown that the traditional genetic algorithm is able to converge to an optimal solution on average in 320 iterations, which takes around 15-20 minutes. The algorithm was shown to be robust and able to find a very good local optimum. A novel enhancement to the genetic algorithm has been devised to improve convergence to the optimal point: narrowing down the area of search as soon as the individuals start to converge to some smaller region, which allows the parameters to keep working efficiently and not miss the optimum due to large mutation jumps. The devised strategy decreased the average optimization time to around 240 iterations. The results have shown the viability of genetic algorithm in electron beam decoupling. The algorithm's success should motivate its usage in various other processes that require optimization. The developed strategy and the analysis of the best parameters improved the efficiency of the algorithm. The improved algorithm can prove useful in solving other optimization problems.