Abstracts - 2008

Searching for a Betatron Tune Working Point for the Proposed Electron-Ion Collider at Jefferson Laboratory

Student: ***Scott Alton***, Michigan State University, East Lansing, MI
Mentor: Yuhong Zhang, Thomas Jefferson National Accelerator Facility, Newport News, VA

The mechanics of relativistic particles in storage rings are well understood. The particles oscillate around the intended orbit in the transverse X and Y directions--called the betatron oscillations. The number of oscillations per orbit is known as the betatron tune. If the betatron tune is an integer or a special resonance value, the oscillations will build in amplitude due to constructive interference and the beam will become less focused. This becomes complicated in the proposed ELectron-Ion Collider at Thomas Jefferson National Accelerator Facility (ELIC). The ELIC will be similar to a storage ring except that there will be beams of particles in both directions through each other several times every turn around the ring. When the beams pass through one another, they give each other a 'kick' which alters the betatron tune often causing it to become one of the resonance values and degrading the beam quality and luminosity, which is a measure of the number of collisions per turn around the ring. This narrows down the range of betatron tunes that are available to operate the collider with a well focused beam. The purpose of this research was to find a betatron tune working point, or a set of betatron tunes in both transverse directions, which optimize the luminosity for both beams. A tune map shows which areas of the tune space are far from resonance values. The tune map was used to choose some betatron tune working points far from resonance. The region that was used was near half integer, because there was a large space on the tune map that was far from the regions of resonance. Simulations were run that broke down the collider rings into a series of linear maps around the ring and elementary forces at the point where the two beams interact. The goal was to find a betatron tune point where the beams stayed focused after many turns. An effort was made to separate the different tunes to find out how each one affected the luminosity but due to the highly nonlinear nature of the forces involved, this was ineffective. A stable working point has been found in the half integer region of the tune map. The point maintained about 65% of its peak luminosity after 30000 turns. This compares well with some of the best working points that have been found which top out at around 70% of the peak luminosity. It was found that there are certainly stable working points in the half integer region, and more points should be explored in this promising region of values. With a good working point, it will be possible to build a high luminosity collider allowing new experiments involving quantum chromo dynamics.

Laser System for Hall C Compton Polarimeter

Student: ***Eric Holland***, Saint Anselm College, Manchester, NH
Mentor: David Gaskell, Thomas Jefferson National Accelerator Facility, Newport News, VA

At Thomas Jefferson National Accelerator Facility a polarized electron beam is used to study the properties of nuclei. Currently, in Hall C a Møller Polarimeter is used to measure the electron beam polarization. This process is accurate but during measurements, the experiment is interrupted (destructive measurement). Since Møller measurements can only be done at low beam current < 1 microAmp and the experiments typically run near 100 microAmps, one has to assume that the polarization remains constant between measurements. To supplement the Møller Polarimeter, Hall C is constructing a Compton Polarimeter, which performs non-destructive electron beam polarization measurement by Compton scattering. The purpose of this research is to optimize the laser component of the Compton Polarimeter. A fiber optic pulsed laser, with the same radio frequency as the electron beam (499MHz), was chosen to improve the luminosity and thus the number of Compton events. The current choice of laser alone would be adequate for Hall C; however, a higher power system would provide two obvious benefits: the time needed for a measurement would decrease, and the signal to background ratio would increase. A Fabry-Perot optical cavity was proposed to achieve a gain in the laser power. Due to cavity conditions and geometrical restraints, it was determined that a cavity of length 1.2 meters would best satisfy the needs of the Compton Polarimeter.

Our results strongly suggest that a gain switched pulsed laser cannot be coupled to an external optical cavity. A possible explanation is that the process of gain switching does not produce a mode-locked pulse train. Within each pulse it is possible that the Gaussian may be coherent but from pulse to pulse the coherence does not held. Mode locking is necessary for realizing a successful optical cavity.

Separating the Spin States of a Free Electron Beam

Student: ***Neil Rifkin***, University of Connecticut, Storrs, CT
Mentor: Douglas Higinbotham, Thomas Jefferson National Accelerator Facility, Newport News, VA

In 1922, Otto Stern and Walther Gerlach set out to test the spacial quantization of the electron by passing a beam of neutral silver atoms through a transverse magnetic field. The interaction of the two projections of the electron's magnetic moment with the magnetic field resulted in a splitting of the beam. However, for some 60 years it was generally accepted that the spin of free electrons, and thus their magnetic moment, could not be measured with an experiment similar to that of Stern and Gerlach. The reason being that the Lorentz force on charged particles is far greater than the force due to the magnetic moment of the electron, thus blurring any desired results. The purpose of this research is to determine the feasibility of splitting the spin states of free electrons. To reduce the Lorentz force, the electrons are passed through a magnetic field whose gradient is in the direction of the electrons' momentum. This eliminates the Lorentz force with the exception of the stray velocities associated with imperfect beam preparation. It was shown with computer simulation that constructing a longitudinal Stern - Gerlach device with a superconducting solenoid results in a measurable separation of the two spin states. A polarization of one half was shown in the tails of the beam with a 10 Tesla meter magnet and a beam with 0.1% velocity uncertainties. The splitting is approximately linear in both the strength of the magnet and the perfection of the beam, therefore a complete splitting is certainly within the realm of possibility. In addition, a polarization booster could be built on the Jefferson Lab beam line to help increase beam polarization. These results show that it is physically possible, and even experimentally achievable, to separate a beam of free electrons with a set-up similar to that of Stern and Gerlach.

Fowler-Nordheim Equation Derived, Explained and Calculated

Student: ***Dominik Gothe***, University of South Carolina, Columbia, SC
Mentor: Charles Reece, Thomas Jefferson National Accelerator Facility, Newport News, VA

Working within the field of superconducting accelerators the problem of field emissions is a common problem diminishing the performance of the accelerator. In order to study this problem and find ways to prevent it and or detect it before large sums of money are wasted because the niobium used in the production of the superconducting radio frequency cavities had a field emitting impurity, an understanding of the theory of field emissions is a prerequisite. There is no better way to gain an understanding of abstract physical functions then by derivative from first hand. Therefore it is the aim of this article to examine the origin of field emitted electrons or the Fowler-Nordheim (FN) equation, illuminate its origins using first principle, evaluate it at several steps throughout the derivative using Mathematica, to provide a solid foundation for anyone working with superconducting radio frequency (SRF) cavities, especially to those involved with work function measurements and calculations. Furthermore it is the aim of this paper to establish an approximation to the transmission current that can easily be evaluated on a pocket calculator. In an effort to derive the FN equation from first principle, the image force, the Fermi-Dirac distribution (F.D.D) and density of states (D.o.S.), and quantum tunneling will be introduced. The results given here agree with Russel D. Young and Erwin W. Müller as well as W. W. Dolan, and the model given is accurate within one one hundreth of a numerically evaluated result. Not only does this paper provide the necessary tools to study work functions, field emission and a basis for all work involving superconducting accelerators however it also provides an approximation that can be evaluated on the spot with a pocket calculator.

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Electropolishing Copper Substrates for Niobium Thin-Film in SRF Technologies

Student: ***Andrea S. Carlini***, Virginia Tech, Blacksburg, VA
Mentor: Anne-Marie Valente-Feliciano, Thomas Jefferson National Accelerator Facility, Newport News, VA

Electropolishing, the electrochemical removal of surface contaminants and microscopic smoothing of metallic surfaces, has been extensively used as a surface preparation technique for niobium/copper (Nb/Cu) and bulk-Nb superconducting radio frequency (SRF) cavities. Electropolishing of Cu is particularly useful to prepare substrates for Nb thin-film coatings in SRF technology at Jefferson Lab. However, surface roughness and impurities on Cu substrates can negatively influence the efficiency of Nb-Coated superconductors. During the electropolishing process, a current is applied ot the Cu substrate which is submerged in an electrolyte bath; Cu atoms on the highest peaks of the surface oxidize to form ions that travel away from the substrate, resulting in a smoothing of the surface. The focus of this project was to improve the electropolishing of Cu by optimization of various parameters. Test samples were polished in a phosphoric acid and n-butanol bath, and later observed with profilometry and scanning electron microscopy (SEM). Here it is shown that a high and low current density (J8), electric current per unit area, was identified for optimum polishing. Variables such as bath age, previous mechanical polishing (MP), time, electrode distance, and J8 combinations were tested to analyze the effect on Cu samples. The results indicate that significant leveling of the Cu surface was achievable through optimization of the parameters considered in this paper. Significant improvements in the efficiency and maximum accelerating field of Cu/Nb cavities may be achievable through this improved electropolishing process at Jefferson Lab.

Development of the SRF Cavity Optical Inspection System
Student: ***Alan Chen***, Virginia Tech, Blacksburg, VA
Mentor: Gianluigi Ciovati, Thomas Jefferson National Accelerator Facility, Newport News, VA

Superconducting radio frequency (SRF) waves are used to accelerate the particles in the accelerator beam through niobium cavities. Thousands of these niobium cavities must be utilized in the construction of the International Linear Collider (ILC) in the near future. However, given the precise nature of SRF technology, even the smallest defects on the inner surface of the niobium cavities can decrease the maximum acceleration gradient well below its theoretical limit. The optical cavity inspection process for locating these defects is a tiring manual process that proves tedious when inspecting multiple cavities. The focus of this project was to increase the efficiency of the scanning of the cavities through the automation of the inspection process. Through the use of basic materials such pulse motors, basic aluminum metal stock and a telescope coupled with a charged couple device (CCD) digital camera for hardware and Visual Basic express 2008 to program the software, the SRF optical cavity inspection system was automated with features including an automated rotational system and a program that automatically scans the cavity for defects. A polar coordinate system was also implemented maping the inner surface of niobium cavity allowing a reference point for locating inner defects that adversely affect the cavity's performance. Upon the project's completion, the cavity inspection process should be far more efficient with automated features and a user-friendly interface that allows more precision in locating the defects. The program will allow each cavity's defects to be repaired through a pinpoint chemical wash technique rather than replacing the entire cell on which the defect is located. The automation of the cavity inspection system will improve the data acquisition efficiently and increase the reliability of the findings as well. The automation of the cavity system will also greatly improve the cost efficiency in which the cavities can be processed and repaired and is a major step in preparing for the construction of the new ILC in the near future.

The Parameterization of SRF Niobium Cavities
Student: ***Filis Coba***, Central Connecticut State University, New Britain, CT Mentor: Andrew Hutton, Thomas Jefferson National Accelerator Facility, Newport News, VA

The Continuous Electron Beam Accelerator Facility (CEBAF) at Jefferson Laboratory uses elliptically-shaped Superconducting Radio Frequency (SRF) cavities to accelerate electrons to energies approaching 6 GV. These cavities are made from sheets of fine-grain niobium that are forged and rolled from a niobium ingot. CEBAF created the so-called 'C-50_ program to refurbish inefficient cavities and increase the accelerator gradient Eacc', while reducing Radio Frequency (RF) losses. The C-50 cavities were treated with Buffered Chemical Polishing (BCP) and High Pressure Rinsing (HPR) to remove any impurities found on the cavity surface. Prior to going into the accelerator, the cavities then were tested using high RF power represented graphically as the quality factor Q0 against the Eacc (MV/m). The focus of this research was to emphasize specific changes commonly ignored in C-50 cavities by linearly plotting the Surface Resistance (nΩ) against the Eacc and by analyzing and parameterizing the middle field of C-50 as well as ILC and DESY cavity plots. The primary step in analyzing the middle field was to convert the Q0 value into the surface resistance. Data was taken for many C-50, ILC and DESY cavities plotted linearly and fitted with various difference parameterization techniques in order to extract a common fit for all cavities. The 4th order polynomial fit equation was the best fit for all cavities, yielding five constants. After numerous manipulations, difference programming and graphing techniques, the results indicate that the following parameterization equation:

R = T + S x E + (R0 – T) x [1-(E/U)2 x [1–(E/V)]2

fits the data, not only for all of the C-50 cavities, but also for the ILC cavities from JLab and DESY. Furthermore, the middle field 'bump' is always present regardless of the difference cleaning methods performed on the cavities. This study makes no attempt to explain the significance of this parameterization, but it does provide an indication of the underlying physics which will be followed in future studies.

Controlling Electron Bunch Spacing with a New Beat Frequency Modulator

Student: ***Heather Graffius***, West Virginia Wesleyan College, Buckhannon, WV
Mentor: Joseph Grames, Thomas Jefferson National Accelerator Facility, Newport News, VA

The Continuous Electron Beam Accelerator Facility (CEBAF) at Jefferson Laboratory uses a DC high-voltage GaAs photogun to supply a continuous train of electron bunches known as the electron 'beam'. The electron bunches are generated by drive lasers pulsing at 499 MHz synchronous with the radio-frequency cavities of the accelerator, consequently the bunch spacing for typical experiments is 2 ns. Experiments at CEBAF can sometimes benefit from the bunch spacing being longer (>10 ns) to allow the detectors to better distinguish time-dependent signal from background, however, the drive laser does nto have sufficient band-width for such low repetition rates (<100 MHz). The focus of this experiment is to implement a device that will use the existing drive lasers, yet allow the electron bunch spacing at the experiment to increase. To achieve this, a new radio-frequency electronic device called the Beat Frequency Modulator (BFM) was constructed. The BFM lowers the repetition rate of the drive laser to a sub-harmonic frequency within an acceptable range (400-500 MHz) so that this new train of electron bunches 'beat' against a fixed 499 MHz radio-frequency chopping cavity, allowing only bunches at the difference in frequencies to pass. The BFM was fabricated and bench tested with a spectrum analyzer. The BFM will be tested with the electron gun and used in an experiment to limit background at the injector Mott polarimeter detectors, by operating with bunch spacing greater than 10 ns. The successful design construction and installation of the BFM will allow physicists at Jefferson Lab to obtain more precise data by going them a range of electron bunch spacing than can dependent on their experiment.

New Wien Filter at the Continuous Electron Beam Accelerator Facility CEBAF)

Student: ***Robert A. Powell, Jr***., West Virginia Wesleyan College, Buckhannon,WV
Mentor: Joseph Grames, Thomas Jefferson National Accelerator Facility, Newport News, VA

A new beam line containing a Wien filter will be installed at the Continuous Electron Beam Accelerator Facility (CEBAF) injector as part of an upgraded 4π spin manipulation system for the PREX experiment. The spin of each of the beam electrons process along the journey from the polarized electron source to the end-station experiment. A Wien filter, a device possessing both an electric and magnetic field, rotates the spin direction to precisely compensate the accelerator journey and control the ultimate orientation at the target. The optically asymmetric nature of the Wien filter, however, must be accounted for and is done so with quadrupole magnets. The focus of this project is to characterize the new Wien filter and beam line. The required magnetic was determined by calculation and compared with measurement. Optimization of the quadrupole magnets is done by defining the beam size and divergence using the code Elegant. It is shown that the analysis and modeling support the beam line design with the intended goal of injecting into the accelerator an electron beam with control over the final spin orientation at the experimental target. This control over the final spin orientation allows for more precise and efficient measurements in each of the experimental halls.

Hydrogen Outgassing in Stainless Steel Gun Chambers

Student: ***Melissa Ricketts***, Merced Community College, Merced, CA

Mentor: Riad Seuleiman, Thomas Jefferson National Accelerator Facility, Newport News, VA

Vacuum quality is an important aspect in electron guns. The hydrogen outgassing rate is a determinant of the vacuum quality in stainless steel gun chambers. A low outgassing rate allows for a better vacuum and therefore a longer photocathode lifetime. Low outgassing rates depend on thermal treatments of the chamber. The purpose of this project is to put together a gun chamber, and assess the hydrogen outgassing rate after an administered thermal treatment. To determine the hydrogen outgassing rate, pressure measurements of the vacuum chamber must be taken. Once these measurements have been obtained, they can be used along with the known volume and surface area of the chamber to calculate the outgassing rate. A thermal treatment of 400o C for nine days achieved an outgassing rate of 1.12 x 10**-13 Torr L/s cm2. The value obtained for the hydrogen outgassing rate is one order of magnitude better than previous outgassing rates. This is because in the past, this specific thermal treatment has never been used. This improvement illustrates the success of the project.

RTPC for Low-Energy α-Particle Detection in the Experimental Search for Hybrid Mesons

Student: ***Nicholas Sharp***, Frostburg State University, Frostburg, MD

Mentor: Stepan Stepanyan, Thomas Jefferson National Accelerator Facility, Newport News, VA

The theory governing the strong interaction between partons (quarks, q and gluons, g) in the standard model of particle physics, quantum chromodynamics (QCD), allows a large variety of bound states, known as hadrons. Any combination of quarks and/or gluons can exist as long as their respective color charges negate to zero. Nearly every hadron observed however is in a qqq (baryonic) or q (mesonic) configuration. These are the particles predicted by the well-known quark model, however so-called exotic states are also allowed by QCD, such as glueballs (gg), pentaquarks (qqqq), hybrid mesons (gq), etc. Some of these short-lived exotic states can be identified by their unique quantum numbers, but others are indistinguishable from ordinary hadrons. The detection of exotic hadrons has so far been shrouded in controversy, and as such we are seeking evidence of the ground state hybrid meson π1 with quantum numbers JPC = 1–+ via photoproduction utilizing the 6-GeV electron beam off of 4He nuclei. A key factor in our experiment is the use of 4He nucleons due to the 4He nuclei being spin- & isospinless, thus greatly simplifying the partial-wave analysis (PWA) thanks to the resulting coherent photoproduction process and subsequent elimination of noise from nucleon-resonance production. The foundation of the experiment however is in the use of a radial time-projection chamber (RTPC) to detect the low-energy recoiling 4He nuclei. The RTPC has cylindrical gas electron multipliers (GEMs) with almost 360° cover- age for detection, similar to the successful barely off-shell nucleon structure (BoNuS) experiment. Two mass-energies have tentatively been detected for the ground-state π1, though there can only be one: 1.4 GeV & 1.6 GeV (theory predicts ≈ 2 GeV/c2). Detection of the π1 at Jefferson Laboratory will be a big step towards ending the controversy surrounding exotic hadrons and furthering our knowledge of the still-elusive quark-gluon behavior and the strong force.

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Assessing the Effects of Magnetic Fields on the Photomultiplier Tubes in the SANE
Student: ***Forrest Smith***, State University of New York, Geneseo, NY
Mentor: Mark Jones, Thomas Jefferson National Accelerator Facility, Newport News, VA

As nuclear physicists work to understand the behavior of the quarks and gluons that comprise nucleons, polarization has become increasingly important. The Spin Asymmetries of the Nucleon Experiment (SANE) at Jefferson Lab used polarization of both beam and target in electron-proton scattering. While the beam can be produced in a polarized state, the target was polarized by way of a strong magnet. This magnet's field was non-negligible outside of the intended region, and this study examined the field and assessed its effect on photomultiplier tubes (PMTs) used in SANE. The magnetic field was mapped with reference to the location of the PMTs, and a statistical analysis of run data from SANE was done using the physics analysis framework developed ROOT. It was concluded that the magnetic field caused, on average, a 3.3% ± 1.8% loss in PMT signal due to the bending of electrons. This minor, but statistically significant, effect is consistent with prior, cursory estimates and solidifies the viability of coming results from SANE. These results also provide a good characterization for the PMTs' performance in a magnetic field and will benefit future experiments in which they are used.

Effect of Temperature on the Surface Morphology of Niobium during Buffered Electropolishing
Student: ***Jennifer Beveridge***, Indiana University of Pennsylvania, Indiana, PA
Mentor: Andy Wu, Thomas Jefferson National Accelerator Facility, Newport News, VA

In order to achieve high acceleration gradients for particle accelerators based on niobium (Nb) superconducting radiofrequency (SRF) technology, Nb cavity surfaces need to be as smooth and as free from impurities and defects as possible. In cavity production, removal of damaged surface layers typically occurs as the final step before rinsing and RF testing. Presently, this is performed by either buffered chemical polishing (BCP) or electropolishing (EP). Buffered electropolishing (BEP), a method developed at Jefferson Laboratory, has been shown to outperform both BCP and EP in terms of surface smoothness and polishing rate. BEP utilizes a mixture of hydrofluoric, sulfuric, and lactic acids to etch away the damaged layer of Nb surfaces. The aim of this research was to study how the surface topography of the Nb changed with varying temperatures during BEP and to better understand the mechanism for the removal of Nb from the surface. BEP was performed on Nb flat samples at temperatures between 7 °C and 44 °C. The smoothness of the Nb surfaces was evaluated via profilometry and atomic force microscopy. To investigate the role of lactic acid in BEP, soluble Nb complexes with lactic acid were proposed. To verify the possibility of these complexes, an electrolyte consisting of only sulfuric and lactic acids was also used to electropolish Nb flat samples. This research indicates that a higher temperature during BEP yields faster polishing rates, maximizing near 32 °C, and that a smoother Nb surface can be obtained via polishing between 21 °C and 32 °C. In addition, this research suggests that lactic acid may form soluble coordination compounds with niobium, aiding hydrofluoric acid in the removal of niobium oxides from the material surface. Coordination of lactic acid with niobium oxides may explain the higher polishing rate of BEP when compared with conventional EP, which contains hydrofluoric and sulfuric acids, but not lactic acid. Further research into the exact surface conditions present during BEP and EP have yet to be explored, but a better understanding of the BEP's temperature dependence and mechanism could advance BEP treatments on Nb SRF cavities.

Software for an Automated Bead-Pull System for the Production of Superconducting Radiofrequency Cavities

Student: ***Stephen Lowery***, Harvey Mudd College, Claremont, CA
Mentor: Haipeng Wang, Thomas Jefferson National Accelerator Facility, Newport News, VA

The propagation of electromagnetic (EM) waves depends on the material through which they pass. The introduction of a small dielectric sphere into a superconducting radiofrequency(SRF) cavity, such as those used at the Continuous Electron Beam Accelerator Facility (CEBAF)at Jefferson Lab, alters the relative phases of the resonating EM fields in the cavity. These phase changes can be used to find the field flatness of the resonant EM modes in a cavity, which is critical to the operation of CEBAF. This measurement is called bead-pulling and is performed several times on each cavity during tuning at Jefferson Lab. The purpose of this project was to write data acquisition software for a preexisting, manual bead-pull system as part of the development of a fully automated bead-pull system. The preexisting bead-pull system consists of a pulley system controlled by an electric motor for moving a dielectric sphere through the cavity being measured and a network analyzer for generating and measuring radio waves in the cavity. The software was developed in the Microsoft .NET framework, runs from a desktop computer and controls and receives data from the network analyzer. The data acquisition software has been successfully implemented. Previously, bead-pull measurements were taken manually and took between half an hour and four hours; with the new software these same measurements take approximately ten minutes. This project shows that a cost-effective automated bead-pull system is feasible and that the cavity tuning facility at Jefferson Lab could save hundreds of hours of labor by implementing this software. The next step in this project will be to automate the mechanical apparatus of the bead-pull system.

Beam. Dynamics studies of 11 GeV Normal Conducting Radio Frequency Separator for 12 GeV Upgrade of Continuous Electron Beam Accelerator Facility

Student: ***Kirsten Dietrick***, Rensselaer Polytechnic Institute,Troy, NY
Mentor: Shahid Ahmed, Thomas Jefferson National Accelerator Facility, Newport News, VA

In recent years, deflecting/crabbing RF cavities have received significant popularity; applications include beam splitting, luminosity upgrade, light source, emittance exchange and beam diagnostics etc. In this paper, we report the beam dynamics studies of parallel-rod type deflecting structures both superconducting and normal conducting. The excited transverse electromagnetic (TEM) π-mode provides deflecting/crabbing kick to the beam. In the deflecting mode of operation, bunch center experiences net force, however, the head and tail are kicked oppositely in crabbing application. This cavity has advantages over the conventional cylindrical cavity operating in TM_{110}-mode particularly at low frequency. Numerical simulations of beam dynamics show significantly small increase in the emittance which is consistent with the analytical estimates. Moreover, the strong concentration of EM fields between the rods make the arrangement of normal conducting cavities insensitive to the mechanical vibrations causing misalignment.

Electron Spin Dynamics in ELIC Spin Rotators and its Visualization Tool
Student: ***James Kotary***, State University of New York at Buffalo, Buffalo, NY
Mentor: Pavel Chevtsov, Thomas Jefferson National Accelerator Facility, Newport News, VA

The Electron-Ion Collider or ELIC is a proposed upgrade to the Continuous Electron Beam Accelerator Facility (CEBAF) in which high-energy polarized electrons will be collided with positively charged polarized ions. Important to the device's role in many nuclear physics experiments is an intrinsic property of particles known as spin, which must be oriented or polarized according to the electron beam's position in the collider. The geometry of the ELIC is important to its spin dynamics, consisting of two circular arcs connected by two linear intersection regions where the collisions are to occur. Effective operation of the ELIC will require longitudinal polarization of spin at the interaction points and vertical polarization in the circular arcs in order to exploit the Sokolov-Ternov effect of electron self-polarization. The redirection of the particle spin between each of these regions is achieved by special devices called spin rotators, each consisting of two solenoids and two horizontal bending magnets. The focus of this project is to develop a tool which will help physicists and accelerator operators to visualize the spin rotation dynamics of an electron beam in the ELIC. For this study, the numerical computing software MATLAB was used to produce a computer-graphics representation of the effect of ELIC spin rotators on electron spin. A Graphical User Interface was developed which accepts user inputs, uses existing theory to compute desired quantities and uses Matlab's graphical capabilities to display the results. The outcome of this project is an easy-to-use tool which allows users to visualize the precession of electron spin in the ELIC spin rotators for any beam energy at which the machine is designed to operate. Physicists will be able to use this software as a convenient means of computing required field strengths for the rotators and obtaining graphical verification of solutions. In addition, it allows for investigation into the effects of changing the physical parameters of the rotators themselves. The theory of spin rotation dynamics is crucial to the design of ELIC, and it is hoped that this study will contribute to a better understanding of the spin dynamics of rotators as plans for the Electron-Ion Collider continue to develop.

Error and Background Radiation Analysis for the Compton Polarimeter
Student: ***Amber McCreary***, University of Pittsburgh, Pittsburgh, PA
Mentor: Patricia Slovignon, Thomas Jefferson National Accelerator Facility, Newport News, VA

Many of the experiments that run in Hall C at Thomas Jefferson National Accelerator Facility require a precise measurement of the electron-beam polarization. Along with the current Moller Polarimeter, a Compton Polarimeter is going to be added, which is non-destructive to the beam, allowing the polarization to be measured at the same time that data is taken. Current simulations for the Compton Polarimeter, which track the properties of the particles as they go through the magnetic chicane and into the detectors, neglect the background radiation that is created, especially when the beam passes through a focusing aperture before it enters the optical cavity of the polarimeter. When the beam goes through this aperture, some of the electrons in the beam halo will collide with the metal, thus creating background radiation. The focus of this project was to adapt the current Monte-Carlo-based Compton simulation to determine the perimeters as to when the background radiation produced by the beam halo will cause significant errors in the data taken in the detectors. Using Fortran, the aperture was created in the Geant3 Monte-Carlo simulation. Then, simulations of the beam halo background radiation were run, and the rates of the particles detected for both backscattering and the beam halo were analyzed. It was found that the halo will not be a significant problem in the detectors, but it will be more of a problem in the photon detector than the electron detector. For the backscattering and halo events to differ by a factor of ten, the fraction of the beam in the halo needs to be smaller than 2E-10, which is 20 times smaller than expected. This means that as long as the beam is focused, the back scattering events will dominate. Setting certain hardware thresholds and software cuts on the detectors, which will cause them to only read a certain energy range, can also improve the ratio of back scattering to halo events. These findings will allow the scientists using the Compton Polarimeter to reduce and estimate the relative size of the contamination coming from the beam halo background radiation. The simulation will also be useful for the design of the 12GeV Compton Polarimeter, allowing scientists to see if the size of the aperture must change as the beam's energy increases and the halo becomes worse.

Maximizing Collider Luminosity through Genetic Optimization of Beam Tunes

Student: ***Matthew Kramer***, University of California, Berkeley, CA
Mentor: Balsa Teraic, Thomas Jefferson National Accelerator Facility, Newport News, VA

In designing a particle collider, one goal is to achieve the maximum feasible luminosity, a measure of the rate of collision events. Luminosity depends, in part, on a set of parameters known as the betatron tune working points (oscillation frequencies) of the beam. The relationship is complicated and nonlinear, making optimization extremely difficult. Researchers have long sought viable algorithms for solving this problem. Here, a massively parallel genetic algorithm was developed and used to locate high-luminosity working points for the proposed Medium Energy Ion Collider currently being designed at Jefferson Lab. The algorithm made use of the BeamBeam3D package to perform beam-beam simulations and to then calculate the luminosity of each working point. It was found that after five or more generations, the algorithm successfully located working points with luminosities exceeding the proposed design luminosity of the collider. These results demonstrate that such algorithms provide a feasible solution to this type of problem. Owing to the parallel evaluation of working points, a large subset of tune space can be covered relatively quickly (one or two days). It is hoped that such methods may prove useful for various other difficult optimization problems in accelerator design.

Betatron Tunes in the Proposed Medium-Energy Electron-Ion Collider at Jefferson Lab

Student: ***Colin Jarvis***, Macalester College, St. Paul,MN
Mentor: Balsa Terzic, Thomas Jefferson National Accelerator Facility, Newport News, VA

The future of Jefferson Lab lies within the construction of a Medium-Energy Electron-Ion Collider (MEIC), which is currently in the proposal stage. In a synchrotron collider storage ring, the orbiting beams oscillate transversely in both the horizontal and vertical directions. The frequency of these oscillations is called the betatron tune. Depending on the design tune of the collider, non-linear beam-beam effects can cause rapid degradation of the beam quality, thus yielding poor luminosity, which is the figure of merit in the MEIC. The non-linear nature of the beam-beam effects poses a serious obstacle to the efficient analysis of potential design tunes. The goal of this research was to find an X and Y betatron tune, or working point, which optimizes luminosity performance. Using code developed at Lawrence Berkeley National Lab, particle interactions were numerically simulated. Beginning with a previously known working point, systematic simulations were run to scan the adjacent tune space. A subsequent working point was discovered that provides a 33 percent increase in theoretical peak luminosity over the current MEIC design.

Using a CO2 Laser to Heat a Gallium Arsenide Wafer
Student: ***Allison Mitchell***, Juniata College, Huntington, PA
Mentor: Marcy Stutzman, Thomas Jefferson National Accelerator Facility, Newport News, VA

Polarized electron beams have a wide application in studies that range from materials science to nuclear and high-energy physics. The Continuous Electron Beam Accelerator Facility of the Thomas Jefferson National Accelerator Facility requires a highly polarized electron beam that is produced by photoemission from a gallium arsenide (GaAs) semiconductor photocathode. Before the photocathode can emit electrons, it must first be heated to near 550°C in a vacuum chamber to remove any oxide from the surface. Currently, the wafer-heating is done by placing a large molybdenum puck, holding the GaAs, on a ceramic heater in the vacuum chamber. The focus of this project was to test if a CO2 laser is a viable alternative to the ceramic heater and capable of heating the GaAs photocathode to 550°C by varying the metal to which the GaAs is mounted. Pucks made both of stainless steel and molybdenum, either bare or coated with a layer of Aerodag vacuum-compatible carbon coating, were placed in a vacuum chamber with a thermocouple attached to the front face, where the GaAs would normally be placed. A 40W CO2 laser, at the infrared wavelength of 10.6 microns, was aimed at the puck within the vacuum chamber through a zinc selenide window, and the temperature on the front surface was recorded as the laser heated the puck. A block of anodized aluminum was also placed in the chamber with a thermocouple attached to it and a 10W CO2 laser was shone at it, while the temperature was recorded. The maximum temperature achieved was 420 °C with the carbon coated stainless steel puck, which is insufficient to remove oxides from a GaAs photocathode. The coated molybdenum reached a temperature near 300 °C, while the uncoated metals only reached temperatures near 200°C. The anodized aluminum was only able to reach a temperature near 120°C. These results indicate that the radiation absorbed by large bare or coated pucks, of either molybdenum or stainless steel, is insufficient to heat the puck face to 550°C. Smaller pucks, a higher power laser, more absorptive coatings or less reflective materials should be investigated in order to heat a GaAs wafer sufficiently using an infrared laser. If such a material is found, then it can be used in a side puck chamber design.

Abstracts - 2011

Student: Anton Zvezdin, State University of New York at Stony Brook
Mentor: Balsa Terzic, Center for Advanced Studies of Acclerators, Thomas Jefferson National

Accelerator Facility, Newport News, VA.

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.

Abstracts - 2012

The Testing of Hall D Beam Position Monitors For Operation On a Low Current Beam.
JOSEPH ATCHISON (West Texas A&M University, Canyon, TX 79015) JOHN MUSSON (Thomas Jefferson National Accelerator Facility, Newport News, VA 23606).

Efficient accelerator operation requires the determination of the electron beam position at various locations along the beam path. The Jefferson Lab Beam Position Monitors (BPMs) are superheterodyne receivers that utilize analog and digital components. The BPMs measure the voltage and phase of the beam and utilize these measurements to determine the position and change in position of the beam, respectively. Hall D requires more sensitive stripline BPMs, which can detect low-current beams. The focus of this project was to test stripline BPMs, before installation. Furthermore, the BPM firmware and new methods of BPM calibrations, including phase measurement calculations and Y-factor calibration, will be tested before utilization in the beam tunnel. To test the BPMs, a Goubau Line system was used to simulate an electron beam. The BPMs were attached to Stac6Si stepper motors, which were used to scan a 1 cm^2 area around the BPM center. The stepper motor position was compared with the BPM data to measure BPM sensitivity. Finally, the BPMs' circuitry and Y-factor calibration methods were tested. It was found that BPM voltage measurements can determine the beam's position with a sensitivity of

1.9 dBm/mm. Furthermore, Y-factor analysis provided real-time measurements of BPM gain and noise factor. The BPM circuitry was found to have an acceptable gain, isolation, and saturation point. It was determined that a 1 mm change in position results in a 4.2° change in phase. It was found that the new BPMs are twice as sensitive as previous models, and, with the use of a perceptron, phase measurements can determine change in beam position, providing feedback for beam operators during BPM calibration. More sensitive position measurements allow researchers to conduct experiments requiring low-current beams, and allow for more accurate electron beam positioning.

Target Mass Corrections to Nucleon Structure Functions. MATTHEW D. BROWN
(Arizona State University, Tempe, AZ 85287) WALLY MELNITCHOUK (Thomas Jefferson National Accelerator Facility, Newport News, VA 23606).

A nucleon (a proton or a neutron) can be described simply as a bound state of three quarks. However, in reality, the structure of the nucleon is complicated by the gluons which bind the quarks together and quark-antiquark virtual pairs popping in and out of the vacuum. This structure is often parameterized by quantities known as structure functions. Structure functions are measured in deep inelastic scattering experiments with nucleon targets, such as the ones conducted here at Jefferson Lab, and then fitted to theoretical conjectures. Because of the high energies involved in the experiments, one may typically assume when postulating theoretical parameterizations that the nucleon mass is negligible compared to the interaction energy. However, in order to obtain a more accurate and complete picture of the internal structure of nucleons, we considered the effects of target mass corrections to nucleon structure functions. Using the operator product expansion of quantum field theory, along with several other mathematical tools, we obtained elegant new formulas for the target mass corrections to all of the usual spin-averaged nucleon structure functions. We also determined the Cornwall-Norton moments of each target mass corrected structure function, quantities which are convenient for numerical studies. Our results are consistent with previous work. However, we have found interesting behavior of the target mass corrected structure functions in what is referred to as the large-x regime. This suggests a relationship between our work and what is known as the threshold problem, one of the most important outstanding questions about the limitations of the operator product expansion.

Slow Controls LabVIEW Program for the Silicon Vertex Tracker. MINNAE P. CHABWERA (Hampton University, Hampton, VA 23668) AMRIT YEGNESWARAN (Thomas Jefferson National Accelerator Facility, Newport News, VA 23606).

The focus of this project was to create a LabVIEW slow controls program for the Silicon Vertex Tracker, SVT, slow controls system. The program will be used to test the modules of the SVT at Fermi National Accelerator Laboratory, Fermilab. The LabVIEW Virtual Instrument, VI, in which the program was created and is currently stored, will run a 72-hour burn-in test on each of the 66 modules of the SVT, while retaining the ability to run shorter, more specific tests. The slow controls VI has been designed for both novice and expert LabVIEW users, while allowing them the freedom to adjust the parameters specifically to their needs. The VI was created with the capability to run with voltage and current as its parameters. The graphical user interface, GUI, of the LabVIEW slow controls program is designed with a user-friendly interface, where each parameter control is labeled and easy to accurately adjust. The main result from the LabVIEW program is the creation of the monitoring program for the detector modules. The VI has been programmed to communicate with the MPOD hardware, make a strip chart of the voltage and current levels, and automatically record data. It has been specifically wired in the block diagram for the computer to communicate with the MPOD crates and resultantly the SVT. The LabVIEW slow controls program reads back the voltage and current from each channel, as well as signals the voltage and current relation to the programs' threshold settings. The results have been a VI that uses voltage and current as its primary parameters and communicates directly to the MPOD hardware. The next steps for the LabVIEW program to be used in Hall B will be the conduction of the burn-in test and expansion to include more parameters such as humidity and temperature.

Development of a Slow Controls Program for the Silicon Vertex Tracker. **KALEE M. HAMMERTON** (Christopher Newport University, Newport News, VA 23606) AMRIT YEGNESARWAN (Thomas Jefferson National Accelerator Facility, Newport News, VA, 23606).

As part of the 12 GeV Upgrade to the Continuous Electron Beam Accelerator Facility (CEBAF) Large Acceptance Spectrometer (CLAS) in Hall B of Thomas Jefferson National Accelerator Facility, the Hall B Instrumentation group is developing a silicon vertex tracker (SVT). The SVT requires that each of its 66 modules be connected to four low-voltage and two high-voltage channels. The voltage will be provided to the SVT by Wiener MPOD mainframes. These mainframes hold low- and high-voltage cards, which have eight and 16 channels, respectively. The objective of this work was to develop a LabVIEW program to set and adjust the voltages and to monitor the set voltages and the current drawn by the detector. The program was built up from the simple network management protocol (SNMP) virtual instruments (VI) provided by Weiner for LabVIEW. A graphical user interface was designed to allow novices and experts to operate the program. The initial program is capable of setting the voltages and reading back the voltages and currents from eight low-voltage channels and 16 high-voltage channels. The program is communicating with the MPOD mainframe and is running error free. The program will be used for the burn-in tests that will be conducted on the modules at Fermi National Accelerator Facility in the fall of 2012. Now that one card worth of low-voltage and of high-voltage channels can be set, changed and monitored, the program can be easily expanded to set and monitor the 264 low-voltage channels and the 132 high-voltage channels needed for the SVT.

Electromagnetic Field Distribution Measurements in a New Deflecting/Crabbing SRF Cavity Using a "Bead Pull" Test. **YOAV LEVINE (**Tel Aviv University, Tel Aviv, Israel 69978) JEAN DELAYEN (Thomas Jefferson National Accelerator Facility, Newport News VA).

The Continuous Electron Beam Accelerator Facility (CEBAF) at Jefferson Laboratory and the Large Hadron Collider (LHC) at Conseil Européen pour la Recherche Nucléaire (CERN), present a need for a deflecting/crabbing cavity. At LHC, this cavity will rotate the beam bunches just prior to collision in order to enhance the luminosity, and at CEBAF this cavity will deflect each bunch to its corresponding experimental hall. A superconducting radio frequency (SRF) deflecting/crabbing cavity was designed and two niobium models were manufactured, one for each facility. Their geometry is designed to allow an optimal electro-magnetic (EM) field distribution, most importantly a horizontal electric field and vertical magnetic field on the main axis. The focus of this project was to measure the actual EM field distribution inside the cavity intended for CEBAF and to track deviations from the numerical simulations conducted prior to its manufacturing. A “bead pull” measurement was conducted, based on the principle stating that when a dielectric or metallic small bead is inserted into a cavity, it perturbs the EM field, causing the resonance frequency of the cavity to shift. A designated LabVIEW program was modified to coordinate measurements of the cavity’s phase shift as beads of different materials and shapes were pulled through it. It was found that the measured on-axis horizontal electric field distribution is satisfactorily consistent with the simulations, exhibiting a symmetric peak of the expected width and magnitude. The on-axis magnetic field measurement demonstrates peaks at the expected positions, but was influenced by the bead over-perturbing the field and needs to be retaken. The off-axis longitudinal electric field measurement demonstrates peaks positioned further away from the center than predicted. Overall, it is shown that the CEBAF cavity exhibits the expected horizontal electric field response to radio frequency excitation, but needs further testing before ready to operate successfully at its intended facility.

Simulating Pressure Profiles for the Free-Electron Laser Photoemission Gun Using Molflow+. **DIEGO MIONG SU SONG CHO** (Wesleyan University at Middletown, CT 06459) CARLOS HERNANDEZ-GARCIA (Thomas Jefferson National Accelerator Facility, Newport News, VA).

The Jefferson Lab Free-Electron Laser (FEL) is capable of generating tunable infrared or ultraviolet laser light by passing a relativistic electron beam through a magnetic undulator. The electron beam is generated in a high-voltage DC electron gun with a semiconducting photocathode, which must be placed in stringent vacuum conditions, an imperative requirement in order to guarantee photocathode longevity. In prospect of an upcoming upgrade of the electron gun, this project consists of simulating pressure profiles to determine if the novel design meets the electron gun vacuum requirements. The method of simulation employs the software Molflow+, developed by R. Kersevan at the Organisation Européene pour la Recherche Nucléaire (CERN), which uses the test-particle Monte Carlo (TPMC) method to simulate molecular flows in three-dimensional structures. Using Molflow+, pressure profiles are obtained along specified chamber axes in the form of linear plots and color-mapped texture graphics. Molflow+ pressure profiles are then compared to measured pressure values in existing electron guns for validation. Outgassing rates, surface area, and pressure were found to be proportionally related. The simulations make evident that the upgraded gun vacuum chamber requires more pumping compared to the existing FEL electron gun vacuum chamber. Since experimental data correlates well with simulation results, the simulations predict that the new electron gun should have similar vacuum conditions to the existing one, with pressures ranging from 4.0×10^{-12} Torr to 4.5×10^{-11} Torr, depending on the outgassing rate after vacuum bake-out. The ability to simulate pressure profiles through validated tools like Molflow+ allows researchers to optimize complex vacuum systems during the engineering design process.

Simulation of the Hall C Compton Polarimeter Electron Detector. **ERIK G. URBAN (Hendrix College in Conway, AR 72034) DAVID GASKELL** (Thomas Jefferson National Accelerator Facility, Newport News, VA 23606).

Experiments at Thomas Jefferson National Accelerator Facility (TJNAF) use a polarized electron beam to make high-precision, electron helicity-dependant measurements in order to probe the fundamental properties of particles. In such experiments, knowledge of the electron beam polarization is required to extract the physics of interest and therefore needs to be tracked precisely. The Hall C Compton polarimeter serves this need by measuring the scattering asymmetry observed between helicity states in polarized Compton scattering. The primary objectives of this project are to update a simulation and analysis package for the electron detector used in the Compton polarimeter in order to better understand the processes influencing the beam polarization measurement, to test the validity of the current analysis methods, and to test for various systematic sensitivities within the apparatus. First, the simulation package was modified to include the current electron detector configuration and to output the necessary information from each event to a data file. Secondly, the analysis package was redesigned to receive this data and analyze it as if it were from a real experimental run. Once both systems were operational, slight systematic changes were made to the simulation but analyzed without accounting for them in order to gauge the systematic uncertainties associated with the beam polarization measurement as a whole. Both systems are currently functional and it is now possible to gauge the systematic uncertainties associated with the polarimeter. Once all of the tests on the simulation are complete, it will be known which method of analysis is most appropriate and which parameters have the largest impact on the overall uncertainty associated with the polarization measurement. With the uncertainty associated with the beam polarization determined, its overall impact on the final precision achievable by the Hall C experiments will be known.

Cresting Algorithm Using Fourier Analysis of Beam Position. RYAN ROUSSEL (Rensselaer Polytechnic Institute, Troy,NY,12180) YVES ROBLIN (Center for Advanced Studies of Accelerators, Thomas Jefferson National Accelerator Facility, Newport News,VA, 23606)

The Continuous Electron Beam Accelerator Facility (CEBAF) accelerator contains two linear accelerators with superconducting radio frequency (SRF) cavities to accelerate electrons. Sinusoidal electric fields are created inside the cavities, such that electrons see a constant potential accelerating them forward. For this to happen, the maxima of the electric fields in each cavity must be precisely matched to the timing of the particles trajectories. Unfortunately, when first starting the beam, imperfections in the accelerator prevent this from happening. Optimization is achieved by modulating the phase of cavities one at a time until the electrons are observed to have the maximum energy. The focus of this project is to improve the process of finding the crest (maxima) phase of multiple cavities by modulating a large number of cavities simultaneously. This was done by modulating the phase of each cavity at a different frequency and observing the position of the beam at a point of high dispersion. The position of the beam over the period of modulation was then Fourier transformed, producing spikes at the frequencies that corresponded to the different cavities. This was repeated with different amplitudes of modulation to fit a relationship between the amplitude of modulation and the Fourier transform spike amplitude, which contained phase information. This algorithm was used to determine the phase of cavities in a simulation of the North CEBAF Linac with an error of 100 microns in beam position measurement. The improved algorithm successfully predicted the correct phase of eight cavities simultaneously to within an error of two degrees. It has been shown that multiple cavities can be crested at the same time through the phase modulation of cavities at different frequencies and Fourier transforming the positions of the resulting beam. This has ramifications for accelerator operation, because it dramatically decreases tuning time needed for beam optimization.

Abstracts – 2013

ABSTRACT

Simulation Additions for the Proposed Hall A Moller Experiment. ALEXANDER BROWN (Virginia Polytechnic Institute and State University, Blacksburg, VA 24060) MARK DALTON (Thomas Jefferson National Accelerator Facility, Newport News, VA).

Hall A of Jefferson Lab currently plans to use a 150 cm beam target of liquid hydrogen (LH_2) in its upcoming Moller Scattering experiment. In order to study the proposed experiment and fine-tune the equipment specifics needed, a simulation was created using the package GEANT4. Initially, the simulation being used to help in the project's planning used target geometry of a single floating cylinder of LH_2. The purpose of this project was to study the effect that aluminum windows on the front and back ends of the target will have on the expected results. To do this, cross section and asymmetry calculations for different interactions in aluminum were added to the program, along with geometry adjustments for the aluminum ends. When the simulation is run with the newly added scattering information occurring in the aluminum windows, the resulting data will be taken into consideration for future figure of merit calculations.

ABSTRACT

Hadron mass corrections in polarized semi-inclusive deep inelastic scattering. STEVEN CASPER (Carnegie Mellon University, Pittsburgh, PA) WALLY MELNITCHOUK (Thomas Jefferson National

Accelerator Facility, Newport News, VA).

We derive mass corrections for semi-inclusive deep inelastic scattering of leptons from nucleons using a collinear factorization framework which incorporates the initial state mass of the target nucleon and the final state mass of the produced hadron. The formalism is constructed specifically to ensure that physical kinematic thresholds for the semi-inclusive process are explicitly respected. We calculate a leading-order cross section from the contraction of a lepton tensor and a hadron tensor, and we find it is a function of mass-dependent scaling variables. Comparison with the cross section without mass corrections shows significant deviation in the kinematic regions of facilities such as Jefferson Lab. The mass corrections will be important to efforts at extracting polarized parton distribution functions from semi-inclusive processes at intermediate energies.

ABSTRACT

Nuclear Effects in the Proton-Deuteron Drell-Yan Reaction. PETER EHLERS (University of Minnesota – Morris, Morris, MN 56267) WALLY MELNITCHOUK (Thomas Jefferson National Accelerator Facility, Newport News, VA).

Scattering experiments using a deuteron target, composed of one proton and one neutron, are currently the simplest way of studying the internal structure of the neutron. The internal structure can be revealed by examining scattering cross sections for certain reactions using deuteron targets. One such reaction is the Drell-Yan process, where a quark and an antiquark for different hadrons annihilate and produce a lepton-antilepton pair. One can express the proton-deuteron (pD) cross section in terms of the proton-nucleon cross sections as well as the momentum distribution of the nucleons in the deuteron, called the smearing function. For this project, an expression for the smearing function of the pD cross section in the Drell-Yan process was obtained while making as few approximations as possible. The results from this project will allow more accurate computation of the pD Drell-Yan cross section, which is especially necessary for lower energy collisions.

ABSTRACT

Beam Diagnostics of the Compton Scattering Chamber in Jefferson Lab's Hall C. ADAM FAULKNER (State University of New York at Albany, Albany, NY) JOHN MUSSON (Thomas Jefferson National Accelerator Facility, Newport News, VA).

Upcoming experimental runs in Hall C will utilize Compton scattering, involving the installation of a rectangular beam enclosure. Cylindrical stripline Beam Position Monitors (BPMs) are not appropriate due to their form factor; therefore to facilitate measurement of position, button-style BPMs are being considered. Button experience is limited at Jefferson Lab, so preliminary measurements are needed to characterize the field response and guide the development of appropriate algorithms for the Analog-to-Digital receiver systems. $\vec{E}$-field mapping is performed using a Goubau Line, which employs a travelling wave to mimic the electron beam, helping to avoid problems associated with vacuum systems. Potential algorithms include look-up-tables, as well as a potential third order power series fit. In addition, the use of neural networks specifically the multi-layer Perceptron will be examined. The analysis of the field response suggests the buttons are accurate to 10 mm, and will be successful in beam diagnostics for Hall C.

ABSTRACT

Non-linear Multidimensional Optimization for use in Wire Scanner Fitting. ALYSSA HENDERSON (University of Virginia, Charlottesville, VA 22903) ALICIA HOFLER and BALŠA TERZIĆ (Thomas Jefferson National Accelerator Facility, Newport News, VA 23606).

To ensure experiment efficiency and quality from the Continuous Electron Beam Accelerator, beam energy, size, and position must be measured. Wire scanners are inserted into the beamline to produce measurements which can obtain beam properties. Extracting physical information from wire scanner measurements begins by fitting Gaussian curves to the data. This study focuses on optimizing and automating this curve-fitting procedure. We use a hybrid approach combining the efficiency of Newton Conjugate Gradient (NCG) method with the global convergence of three nature-inspired (NI) optimization approaches, which ensures the quality, robustness, and automation of curve-fitting. Given an initial data-derived guess, each finds a solution with the same chi-square-- a measurement of the data-to-fit agreement. The procedure begins with NCG and escalates to a NI method only if NCG fails, thereby ensuring a successful fit. This method allows for the most optimal signal fit and can be easily applied to similar problems.

ABSTRACT

Optimization of Spin-Polarization of Helium-3 Target Cell by Thermal Convection Processes. STACY E. KARTHAS (University of New Hampshire, Durham, NH 03824) PATRICIA SOLVIGNON (Thomas Jefferson National Accelerator Facility, Newport News, VA).

Spin-polarized Helium-3 (^{3}He) cells have been used in many experiments at Jefferson Lab as effective neutron targets to get access to the neutron properties. To reduce the polarization gradient within the cell we studied the new convection system and its effects on adiabatic fast passage (AFP) polarization loss that results from measuring the polarization of Magnetic Resonance (NMR). A Kapton flexible heater was used to induce convection within the cell. By methods of NMR polarimetry, the convection speed and AFP loss was found for multiple heater powers. It was found that an appropriate gas velocity of 6.05 cm/min was easily achievable with an absolute AFP loss below one percent in both the pumping and target chambers. These results indicate that this heater will be able to be used to induce convection in the new cell with small AFP losses.

ABSTRACT

Formulism for R, the Longitudinal to Transverse Momenta Ratio, Within the Quark Parton Model. DANIEL KOCH (San Jose State University, San Jose, CA) WALLY MELNITCHOUK (Thomas Jefferson National Accelerator Facility, Newport News, VA).

When nucleons are struck by a beam of electrons, the scattering process is a combination of the beam's energy as well as the primordial motion of the quarks within the nucleon. Until recently, it has been assumed that at high Q^2, the transverse moment k_T of the parton was negligible. However, new experiments at low Q^2 suggest that k_T dependence may indeed play a significant role. The exact k_T dependence based on theoretical grounds is still unknown, and is the major objective of this project. We examined previously laid theoretical groundwork for R ($R = \sigma L/\sigma T$) and improved them. In particular, we updated several of their formulas using modern techniques and distribution functions. If our theoretical models match well with the data, it will prove that k_T dependence can no longer be ignored. At low Q^2, this primordial transverse momentum will need to be more accurately studied.

ABSTRACT

Evaluating the Field Emission Characteristics of Al and Cu Electrodes for DC High Voltage Photo-Electron Guns. *RHYS TAUS (Loyola Marymount University, Los Angeles, CA 90045) MATTHEW POELKER (Thomas Jefferson National Accelerator Facility, Newport News, VA).*

High current photoguns require high power laser light, but only a small portion of the laser light illuminating the photocathode produces electron beam. Most of the laser light (~ 65%) simply serves to heat the photocathode, which leads to evaporation of the chemicals required to create the negative electron affinity condition necessary for photoemission. Photocathode cooling techniques have been employed to address this problem, but active cooling of the photocathode is complicated because the cooling apparatus must float at high voltage. This work evaluates the field emission characteristics of cathode electrodes manufactured from materials with high thermal conductivity: aluminum and copper. These electrodes could serve as effective heat sinks, to passively cool the photocathode that resides within such a structure. However, literature suggests "soft" materials like aluminum and copper are ill suited for photogun applications, due to excessive field emission when biased at high voltage. This work provides an evaluation of aluminum and copper electrodes inside a high voltage field emission test stand, before and after coating with titanium nitride (TiN), a coating that enhances surface hardness.

2014

ABSTRACT

Multi-Objective Optimization of Heat Load and Run Time for CEBAF Linacs Using Genetic Algorithms. CODY J. REEVES (University of Florida, Gainesville, FL, 32611) BALŠA TERZIĆ (Old Dominion University, Norfolk, VA, 23529) ALICIA HOFLER (Thomas Jefferson National Accelerator Facility, Newport News, VA, 23606).

The Continuous Electron Beam Accelerator Facility (CEBAF) consists of two linear accelerators (Linacs). Each Linac consists of 200 niobium cavities that use superconducting radio frequency (SRF) to accelerate the electrons. The gradients for the cavities are selected to optimize two competing objectives: heat load (the amount of energy required to cool the cavities) and trip rate (how often the beam turns off within an hour). The resulting system is a multidimensional, multi-objective, nonlinear system of equations that is not readily solved by analytical methods. The study employed a genetic algorithm (GA), which applies the concept of natural selection, to solve this system of equations. This paper enumerates several methods to significantly reduce computation time without degrading solution quality. It also demonstrates ability to employ GA for operational use for any Linac-based facility.

ABSTRACT

Simulation of the Hall C High Momentum Spectrometer Drift Chambers. JONATHAN E. STELZLENI (Purdue University, West Lafayette, IN 47906) MARK JONES (Thomas Jefferson National Accelerator Facility, Newport News, VA, 23606).

The drift chambers of the High Momentum Spectrometer (HMS), in Hall C of Jefferson Lab, are used to determine the trajectory of particles. The main focus of this project was to simulate the drift chambers, obtain their properties, and compare to the HMS drift chambers. Garfield++, a simulation toolkit derived from ROOT, was used to simulate the drift chamber. Using this toolkit, a cell of the drift chambers was successfully simulated with properties comparable to the drift chambers of the HMS. The electric fields surrounding the sense wires, in both the simulation and the HMS chambers, were found to be slightly different. Drift velocities were also compared, which showed similar values, but because the different electric fields and accidentals in the HMS data they were not exact. Garfield++ provides many additional functions, such as the simulation of electron avalanches and high energy electron tracks, which are explored. These simulations help to provide insight into how drift chambers function in practical use.

ABSTRACT

Automatic Surface Defect Detection in Superconducting Radio Frequency Cavities using C++ and OpenCV. DANIEL IRIKS (Santa Rosa Junior College, Santa Rosa, CA 95401 / Sonoma State University, Rohnert Park, CA 94928) GRIGORY EREMEEV (Thomas Jefferson National Accelerator Facility, Newport News, VA 23606).

Thomas Jefferson National Accelerator Facility conducts research, development, and production of superconducting radio frequency cavities for particle accelerators. In cavity production, serious albeit tiny surface defects can remain after polishing and cleaning, and these defects limit accelerator efficiency and performance capabilities. The manual inspection process for these defects is very time-consuming. The purpose of this project was to further develop and test an approach to automating defect detection, which could increase cavity production efficiency by decreasing the time and labor necessary for inspection and testing. This approach was to use the programming library OpenCV and the language C++ to write a computer program that would inspect pictures of cavity surfaces and detect defects. In this project, the features of automatic application to multiple pictures, name recording of pictures with detected defects, and defect sizing were added to the program. Also, the program was trained to detect a different type of defect, and its performance detecting this type was tested. Testing showed the program had a detection rate of 53% and a false positive rate of 29%, that the average calculated size was 5 times larger than the actual value with a percent relative average deviation of 30%, and that the average program run time was 2.1 seconds per image. These results are inconclusive as to the feasibility of this program's use for automatic cavity inspection. While sufficient detection and false positive rates were not attained in this project, it may be possible to do so by implementing certain improvements in the training procedure and making changes to certain program parameters.

A

ABSTRACT

Extracting Free Neutron Data from Electron Deuteron Scattering in an Electron Ion Collider. OZ AMRAM (Carnegie Mellon University, Pittsburgh, PA 15213) DOUGLAS HIGGINBOTHAM (Thomas Jefferson National Accelerator Facility, Newport News, VA 23606).

The lack of free neutron targets has made it very difficult to study the internal structure of the neutron with high precision. The construction of a new Medium-energy Electron Ion Collider (MEIC) would allow us to use electron-deuteron scattering to obtain free neutron data by tagging the spectator proton. The focus of this project was to test a new model independent method of extracting the neutron structure function (F2N) from simulated cross section data. It was shown that the model independent method converges to a single value of F2N reliably for cross section data with limited random error. A model dependent modification of the method was shown to reduce error in the extracted F2N. This result demonstrates the proof of concept for a model-independent way of extracting F2N from cross section data. A better extraction of F2N from electron-deuteron scattering would fill in one of the major longstanding gaps in our knowledge of nuclear structure.

ABSTRACT

Comparing and Improving Quality Factor (Q_0) Data Collected from Testing in the VTA, CMTF and Tunnel. Mowafeg E. Abdelwhab (Morehouse College Atlanta, Georgia 30314) EDWARD F. DALY (Thomas Jefferson National Accelerator Facility, Newport News, VA 23606).

The Superconducting Radio Frequency (SRF) Institute at Jlab uses three methods to test RF cavities for quality factors (Q_0): Vertical Test Area (VTA), Cryomodule Test Facility (CMTF), and in the tunnel. The VTA uses an electrical method to calculate Q_0 and the CMTF and tunnel use calorimitry. Participation in each of the three test methods was completed to attain data that can be analyzed to possibly find improvements in the testing techniques and the instrumentation. Since the VTA provides the best environment for the niobium cavities, it is expected that the higher Q_0 values be found using the VTA. However, if the environment and conditions for attaining higher Q_0 values are met in the cryomodule design and the tunnel, it is possible to improve the values in the CMTF and tunnel.

ABSTRACT

Analytic Solutions for Compton Scattering in the High Energy Regime. TODD HODGES (Arizona State University, Tempe, AZ 85004) WALLY MELNITCHOUK (Thomas Jefferson National Accelerator Facility, Newport News, VA 23606).

Thomson sources of electromagnetic radiation utilizing relativistic electrons have seen increased use in fundamental physics research in the past several years. The small frequency range, or bandwidth, of the emitted radiation is highly desirable for applications in nuclear physics, medicine, and homeland security. As the intensity of the incident laser pulse involved in the scattering event increases, the bandwidth of the emitted radiation increases. In accelerators, this increase in bandwidth may be negated through frequency modulation of the laser pulse. However, current analytic solutions governing this frequency modulation are only applicable when the energies of the individual photons in the laser pulse are within the Thomson limit. We derive analytic solutions applicable to laser pulse frequency modulation both within, and outside, the Thomson limit through the use of Quantum Electrodynamics (QED). Specifically, an expression for the differential cross section pertaining to Compton scattering is derived for a reference frame in which both the electron and incident photon are moving. Additionally, an approximation for the differential cross section is derived including first and second order corrections. Progress towards altering the derived expression to include the contribution from multiple photon emitting processes and allowance for specification of incident photon polarization is discussed.

ABSTRACT

Computing Emittance for Non-Gaussian Beam Distributions. CHARLES MCINTYRE (Reed College, Portland, OR 97202) TODD SATOGATA (Thomas Jeerson National Accelerator Facility, Newport News, VA 23606).

We analyze recent data to compute the emittance and Twiss parameters forthe electron beam at Jefferson Lab's Continuous Electron Beam Accelerator Faciliity (CEBAF). The beam is sent through a focusing quadrupole; after focusing, the beam's intensity as a function of transverse position is measured using wire scanners. We develop tools to fit intensity data with both Gaussian and skew-Gaussian distributions, and use the fit parameters to extract mean-square beam size. Analysis of beam size data as a function of quadrupole strength yields the emittance and Twiss parameters. Parameter values are computed in the horizontal plane at 9 points in the accelerator, and in the vertical plane at 6 points. Values for emittance range between $1\text{x}10^{-9}$ and $6\text{x}10^{-9}$. Values for Twiss parameters are found to deviate from design values by up to 2000%, indicating a poorly tuned beam at the time of measurement.

ABSTRACT

Automatic Wire Scanner Fitting Algorithms, VICTORIA GABRIELLE, (University of Virginia, Charlottesville, VA 22094), ALICIA HOFLER & BALSA TERZIC, Thomas Jefferson National Accelrator Laboratory, Newport New, VA 23606

The Continuous Electron Beam Accelerator Facility (CEBAF), uses harp wire scanners to characterize the electron beam as it passes through the entire beamline. Harps operate by scanning through cross sections of the beam while recording position and induced wire current. The operational tool used in the control room is the harpAnalyzer fitting algorithm, which identifes intensity peaks and fits each peak to a Gaussian distribution using the Levenberg-Marquardt (LM) numerical method. The harpAnalyzer toolis useful over a wide range of harp data scans, but occasionally fails to fit harp data or misinterprets peak location entirely, leading to an erroneous computation of beam emittance. This study details an automation system for a new analyzer tool, harpFit which contains a reimplementation of the harpAnalyzer algorithm with added functionality and alternative, Nature-Inspired Methods (NIM) for

increased robustness. The criterion for comparison of the tools was the ability to identify the correct number of intensity peaks. Once peaks have been identified, the tools must generate a Gaussian that accurately fits each intensity peak location, width, and amplitude against hand-tabulated predictions. A final test was a comparison of error and non-normalized chi-square measurement. Testing of 160 scans chosen in both systematic and at random batches showed that harpFit produced output to higher precision, even for problematic data sets. For peak data that had an approximately constant noise oor, reasonably spaced peaks, and peaks with ample data points, the new tool and old tool preformed with the same level of accuracy. In sets that held more noise, sharper peaks and shorter distances between peaks harpFit still produced reasonable output while harpAnalyzer did not. In those cases, the harpAnalyzer algorithm would either crash or fit noise instead of a peak. Across each metric, harpFit used in conjunction with the new peak finding routine and automation system has higher reliability and trouble-shooting abilities than the old tool. By having a more reliable algorithm, the data provided can now give a quantitative measure of beam merit as the beam travels, which is imperative for the design and execution of accelerator experiments.

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ABSTRACT

MULTI-PASS STEERING: A REFERENCE IMPLEMENTATION.

MICHAEL HENNESSEY (McDaniel College, Westminster MD, 21157) MICHAEL TIEFENBACK (Thomas Jefferson National Accelerator Facility, Newport News VA, 23606).

Thermal expansion, inelastic ground creep, and other phenomena change the shape of Continuous Electron Beam Accelerator Facility (CEBAF) at JLab and measurably alter the beam path. Effects of displaced magnetic centers of quadrupole magnets can be observed in historic beam position data. A process exists to determine how the beam line is perturbed from the ideal and to compute corrections that will bring the separate beams of differing energies back to a coincident path. A previous method, tested in 2007, showed that the existing correctors in the linac are sufficient to steer the higher energy beams to coincidence. We introduce a reference implementation of a protocol to compute corrections that bring all the beams back to axis, including, with a larger tolerance, the lowest energy pass using measured beam trajectory data. This method relies on linear optics as representation of the system; we treat each perturbation as a magnetic field error localized to a region between cryomodules, providing the same transverse momentum kick to each beam. We produce a vector of measured beam position data with which we left-multiply the pseudo-inverse of a coefficient array, A. This coefficient array describes the transport of the electron beam through the linac using parameters that include the magnetic offsets of the quadrupole magnets, the instrumental offsets of the BPMs, and the beam initial conditions. This process is repeated using a reduced array to produce values that can be applied to the available correcting magnets and beam initial conditions. We show that this method is effective in steering the beam to a straight axis along the linac by using our values in `elegant`, the accelerator simulation program, on a model of the linac in question. The algorithms in this reference implementation provide a tool for systematic diagnosis and cataloging of perturbations in the beam line. This is operationally useful in the absence of regular beam-line offset surveys and provides a utility to alert the operators of perturbations beyond a specified tolerance, as in the case of hardware misalignment following maintenance activity. In this work we examine transverse deflecting fields in the linear accelerating (linac) regions resulting from these perturbations of the accelerator. The implementation of this tool -with more maintainable programming than is presented here- will contribute to the more efficient operation of CEBAF, as well as provide an archive of data to be used in future diagnostics of the accelerator.

ABSTRACT

Electron Beam Focusing in Linear Accelerators (linacs) LUIS JAUREGUI (California State University, San Bernardino, San Bernardino, CA 92407) YVES ROBLIN (Thomas Jeferson National Accelerator Facility, Newport News, VA, 23606).

The electron accelerator at Je↵erson Lab is used for electrons and nuclei collisions in order to examine the structure of matter. To produce consistent data, it is critical to have a well-focused beam of constant size. To keep the beam focused, quadrupoles (quads) are used. Quads are magnets which focus the beam in one direction (x or y) and defocus in the other. When two or more quads are used in series, a net focusing e↵ect is achieved in both vertical and horizontal directions. The focal length of the quad depends on both the momentum of the particles passing through and the magnetic fields inside the quads. Ideally, the radio frequency (RF) cavities at Je↵erson lab would have constant electric fields for all runs, causing the momentum to be the same at each quad in every run. In actuality, at start up there is a 5% calibration error. This means that the momentum of particles passing through the quads isn't always what is expected. The objective is to find exactly how sensitive the focusing in the linac is to this 5% error. To analyze the electron beam through the linac, the software ELEGANT (ELEctron Generation ANd Tracking) was used. First a simple arrangement of quads was simulated to see how the beam behaved when there was no increase in momentum. Following that, a full linac was simulated, which contained 208 RF Cavities with constant electric fields, a total momentum kick of 1090 MeV, and quads with the appropriate magnetic fields. Next, the electric fields in the RF cavities were randomly decreased in some, while being randomly increased in others, while maintaining a total momentum kick constant. Here we show that when the fields in the RF cavities randomly vary by up to 5%, the beta functions only change by a couple of percent as compared to the ideal case. The linac's focusing is sensitive to this 5% calibration error, but the response is not very large. If this calibration error is to ever be reduced to near 1%, or lower, we can expect the e↵ect on the focusing to be nearly negligible.

ABSTRACT

Tomographic Reconstruction of Particle Beam Distributions. TYLER BLANTON (University of North Carolina at Chapel Hill, Chapel Hill, NC 27599) BALSA TERZIC (Thomas Jefferson National Accelerator Facility, Newport News, VA 23606).

In the areas of plasma and charged particle beam diagnostics, computed tomography (CT) is used to reconstruct a beam's two-dimensional (2D) particle distribution using only 1D line-of-sight intensity projections. This reconstruction may be accomplished using either 1D or 2D mathematical transforms, depending on whether or not the beam is cylindrically symmetric. In practice, only a relatively small number of intensity projections (e.g., 10–100) can be measured, and these measurements are susceptible to both signal-independent (Gaussian) and signal-dependent (Poissonian) noise. These conditions have been shown to cause both the 1D and 2D methods to perform poorly when no denoising procedure is used. In this study, we attempted to improve the performance of particle beam CT in noisy environments by exploring the effectiveness of wavelet-based denoising for both the 1D and 2D reconstruction methods. We created a program which reconstructs a beam's particle distribution from simulated noisy intensity projections for both the 1D and 2D cases. Both methods include the option to utilize a wavelet-based denoising procedure on the intensity projections before the reconstruction process in an effort to maximize the signal-to-noise ratio (SNR) of the reconstructed distribution. We found the denoising procedure to greatly improve the SNR in noisy environments for both the 1D and 2D methods. The 1D method still struggles in high noise environments – especially with plasma distributions which are nonzero at the boundary – but preliminary results suggest the 2D method may be more successful. If so, the benefits of the wavelet-based denoising algorithm implemented in the 2D reconstruction method could potentially assist in the area of particle beam diagnostics.

ABSTRACT

Using Statistical Analysis to Extract Meaningful Beam Position Monitor Data. Eric Thompson (Christopher Newport University, VA 23606) Rui Li (Thomas Jefferson National Accelerator Facility, Newport News, VA 23602).

Throughout the Continuous Electron Beam Accelerator Facility (CEBAF), there are Beam Position Monitors (BPMs) designed to track the position of the beam as it travels through the accelerator. These BPMs record the X and Y position of the beam at specific locations along the beamline. In particular, rayTrace experiments scan a few chosen kickers (devices which change or 'kick' the beams orbit), and store the X and Y positions of the resulting beam orbits in 'rayTrace' data file. These BPM data are composed of betatron orbits, machine perturbation, and noise. However, it is often not a straightforward process to separate physical signal from noise. Therefore, meaningful data needs to be extracted using statistical analysis. This statistical analysis is typically Singular Value Decomposition (SVD), or Model Independent Analysis (MIA). The focus of this project was to extract the betatron orbits from the noise, identify which BPMs are not operating as expected, and compare the betatron orbits with the existing model, Elegant. In this data analysis, the collected rayTrace data was processed using SVD, and the eigenvectors and eigenvalues were plotted, with the number of orbits and number of BPMs varied to check consistency. Using this method, two primary results were shown. The first is that if more BPMs and orbits are included in the processing, then the plots exhibit clearer, more distinct behavior as well as greater consistency. The second result was that several BPMs were identified as being potentially faulty. These results are significant because it was previously believed that processing BPM data for a beamline section of interest would be enough to provide an accurate representation of the data; for that section; however this study has shown that including more BPMs downstream of the section can provide cleaner and consistent extraction of the betatron orbits. It has also shown that Singular Value Decomposition is a preferred method of statistical analysis over traditional covariant matrix calculations due to it being a simpler and more direct method. These findings will allow machine physicists to more accurately analyze the BPM data (or specifically rayTrace data) collected, determine faulty BPMs, and verify that the Elegant model is working as expected.

ABSTRACT

Bench Tuning of the 748.5 MHz Normal Conducting Separator Cavities for 4-Hall Beam Delivery. ANDREW JACOBS (Benedictine College, Atchison, KS 66002) HAIPENG WANG and MARK WISSMANN (Thomas Jefferson National Accelerator Facility, Newport News, VA 23606).

A new 748.5 MHz separator cavity was designed to be able to provide a simultaneous 4-hall beam delivery to each hall of the CEBAF accelerator. Four of these new separators were installed in the fifth pass of the accelerator as a part of the 12 GeV Upgrade project. The cavity is a 4-rod per cell, transverse electromagnetic wave (TEM) normal conducting radio frequency (NCRF) separator cavity. The cavity is split into two cells that are coupled by magnetic slots. The cavity's power is fed through a coupler placed in one of the cells in the form of a copper loop. In this study, the tuning paddles located in the center of each cell should allow for the creation of field flatness (fields of equal strength) in each individual cell before the introduction of the coupler; however, this is not the case with the couplers providing relatively weak coupling and causing a lack of field flatness. The three main methods used to solve this problem are bead-pull bench measurements, computer simulations, and high-power testing. The bead-pull measures the field-flatness in the cavity while it is on the bench, not under vacuum, and the water heating/cooling system is not being used. The computer simulations allowed for the comparison of different coupler loop sizes and its effect on the power coupling and change in field flatness. Lastly, the high power tests were used to test the maximum input power while keeping power reflection at a minimum, cavity frequency stability with water temperature control, and to monitor the field-flatness. All this was done while the cavity was under vacuum and the water heating/cooling system was running. From the data collected, we have shown that the lack of field-flatness is caused by a lack of coupling. For example, when a coupler loop that is under-coupled is used there is a field difference of over 10°. However, when a coupler loop that is over-coupled is used, there is a field difference of less than 1°. These results indicate that coupling must be maximized to solve the problem of field flatness. To maximize coupling, the shape of the coupling loops will need to be altered, along with the orientation of copper rods located on the interior of the cavity. The data collected is also intended to allow for the cavities to be tuned to 748.5 MHz, operate with field flatness, and power in critical coupling. The bench tuning procedure that has been developed will utilize the tuning knobs (hardware) to tune all of the production separator cavities to all three target parameters: operation frequency, critical power coupling, and field flatness between the two cells. This in turn will allow for CEBAF to simultaneous deliver beam to all 4 experimental halls as part of the post 12 GeV Upgrade project.

ABSTRACT
Niobium Thin Film Morphology Characterization for Thin Film Technology Used in Superconducting Radiofrequency Cavities.YISHU DAI (St.Olaf College, Northfield, CA 55057) ANNE-MARIE VALENTE-FELICIANO (Thomas Jefferson National Accelerator Facility, Newport News, VA, 23602).

Superconducting Radiofrequency (SRF) is used in accelerators to propel particle beams by resonating electric fields in superconducting structures called cavities, typically made of bulk niobium (Nb). However, RadioFrequency (RF) only penetrates about 40-100 nm of the top Nb surface thus SRF is considered as a surface phenomenon. Nb thin film SRF technology is based on the deposition of a thin Nb layer (1-2 μm) on top of a good thermal conducting material such as aluminum or copper. Another motivation for thin film is its negligible response to the Earth's magnetic field, eliminating the need for magnetic shielding of the cavities. Superconductivity in thin films heavily depends on the surface quality. Thus topography, which is closely related to conditions of preparation in the coating process, involving controllable parameters such as crystal plane orientation, substrate temperature, ion energy (substrate bias voltage), and deposition rate. Different characterization methods, such as atomic force microscopy, scanning electron microscopy, profilometry, and optical microscopy, are used to collect data on the surface's topographical characteristics such as roughness and film thickness. Analysis methods include Electron BackScatter Diffraction (EBSD), which analyzes the plane orientations of crystals, and atomic force microscopy, which measures the surface roughness and characterize the surface morphology. Through characterization, it is evident that a moderate nucleation energy (~ 120eV) and a long coating time increases the film quality deposited on the r-plane sapphire crystal orientation. Both the growth feature and the quality of the film increases with its thickness. Nb films coated on r-plane, grow along the (001) plane and yield a much higher RRR compared to the films grown on a- and c-planes respectively as Nb (110) and (111). This information allows for further improvement on the research and development process for thin film technology used in superconducting cavities for the Continuous Electron Beam Accelerator Facility at Jefferson Laboratory.

ABSTRACT

Superconducting Cavity to study Surface Resistance. KHENSU-RA LOVE EL(Morehouse College at Atlanta, GA 30314) HYEYOUNG PARK (Thomas Jefferson National Accelerator Facility, Newport News, VA,23606).

A uniquely designed Superconducting Radiofrequency (SRF) cavity will be used to study surface resistance as a function of frequency, surface magnetic field, and different cavity processes. In minimizing surface resistance, the Quality (Q) factor, and energy efficiency, increases. While physicists have discovered a theoretical equation that relates the surface resistance and Q factor, it is only valid for a small range of data relating the two. The accumulation of test results and recent findings urge us to better understand the surface resistance of superconductors. As a result, the focus of this study is to advance the limited knowledge on surface resistance as a function of frequency, magnetic field strength, and different processes to find a better-fitting equation. The procedure of this study includes designing, fabricating, and testing a cavity suitable for this study. The current focus in the project is the fabrication which includes verifying the unique weld, determining the structural strength of the cavity's shell, and confirming the functionality of the cavity's variable input coupler. It was determined that the same weld parameters from the weld test could also be applied to the entire cavity during the fabrication process, and the cavity's structural strength met all safety requirements. However, due to the extensive and meticulous testing period, which ranges from 1-2 years, no results for the cavity study were achieved yet. If ideal results were obtained, this would lead to the derivation of a more accurate equation for the relationship of surface resistance as a function of frequency, magnetic field strength , and other processes. Ultimately, the data could possibly assist in the creation of better cavities by improving their Q factor which would also lower the cost in running any experiments dealing with SRF conductors.