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ABSTRACT

MULTI-PASS STEERING: A REFERENCE IMPLEMENTATION.

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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

The Unpolarized Transverse Momentum Dependent Distributions from JLab6 Data

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Abstract:

The quark structure of the nucleon is one of the main areas of research in modern nuclear physics. Historically only the information on the momentum fraction of the nucleon's longitudinal momentum carried by partons was accessed in the deep inelastic scattering (DIS) experiments. Parton distribution functions (PDFs) and fragmentation functions (FFs) have been extensively studied and libraries of parametrizations of PDFs extracted from experimental data are accessible. The Semi-Inclusive Deep Inelastic Scattering (SIDIS) experiments and measurements of differential cross sections in terms of transverse momentum dependence (TMD) of the produced hadron allow for the construction of TMDPDFs and TMDFFs that will lead to new insights into the structure of the nucleon. Novel theoretically proposed TMDPDFs and TMDFFs will be needed to construct similar libraries for TMD cross-section calculations. The goal of this project consisted of analyzing, and fitting the unpolarized JLab6 SIDIS experimental data to proposed Gaussian based models for TMDPDFs and TMDFFs. The fitting, data analysis, and error analysis was conducted using Python. The least squares method was invoked for the fits, pylab imported packages for the creation of plots, and the error analysis was done using a Monte Carlo simulation with randomized initial conditions. Initial results for the parameterization and minimization of the TMDPDFs and the TMDFFs resulted in improvements on reported literature values. Furthermore, the proposed Gaussian models were able to fit both sets of data with χ^2 values of 1.47 and below. Monte Carlo error analysis on the JLab6 data revealed that approximately 20 000 fits failed to generate statistically distinct parameter values. This led us to conclude that the JLab6 data lacked the proper resolution to be analyzed for TMD fitting parametrizations. Future experiments with JLab12 will be essential for the advancement of TMD phenomenology research.

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.