

## ABSTRACT

Minimizing Kick and Slope of Intermediate Bunches for Electron Cooling. ANDREW DOTSON (Old Dominion University, Norfolk, VA, 23529) ANDREW HUTTON, BALS TERZIC (Thomas Jefferson National Accelerator Facility, Newport News, VA, 23606).

Ions in the Electron-Ion Collider (EIC) at Jefferson Lab have transverse energy (heat), which limits the beam density. In electron cooling, a beam of cool electrons is directed along the ion beam with the same velocity. The ions transfer heat to the electron bunches, cooling the ions. Generating the current needed is beyond the state of the art, but the required current can be reached by reusing electrons and incorporating RF kicker cavities to supply a pulsed electric field that continuously replaces every 11<sup>th</sup> bunch in the cooling ring. A design exists that does this, and yields zero kick and slope to all intermediate bunches in the cooling ring. The design is based on a cosine series with 11 terms in it and requires four separate kickers. The goal of this project is to determine if solutions exist that provide sufficiently small kick and slope, but require fewer kicker cavities. Solutions are evaluated by minimizing an objective function through Sequential Least Squares Programming (SLSQP). Constructing a Pareto front will expose if using 1, 2, 3 or 4 kickers is necessary. An acceptable solution using a single kicker and only the 1<sup>st</sup>, 3<sup>rd</sup>, 5<sup>th</sup>, 7<sup>th</sup> and 9<sup>th</sup> harmonics has been identified. The Pareto front provided insight as to how much less average slope and kick is imposed onto the intermediate bunches when using more kickers, and which harmonics are the optimum combination.

A Comparison of the Legacy TDC and QDC Versus the FADC 250. ALI GENTILINI (Tidewater Community College at Portsmouth, VA, 23703). BRAD SAWATZKY (Thomas Jefferson National Accelerator Facility, Newport News, VA 23606).

Jefferson Lab uses a system of software, hardware, and detectors in every experiment on site. In the field of nuclear physics, even the slightest improvements in each of these areas can open up a world of new discovery. In order to keep up with the science behind these experiments, it is necessary to implement the use of cutting edge electronics and detectors. Older systems use well understood modules such as a Time-Digital Converter(TDC) and a Charge Analog-Digital Converter(QDC). The Flash Analog-Digital Converter(FADC) is a module designed by Jefferson Lab and has the ability to do the work of both the TDC and the QDC in one compact piece of equipment; but lacks the long history of experimentation, documentation of resolution, and error that the TDC and QDC have. The purpose of this experiment is to compare both the timing resolution of the TDC, and the pulse shape discrimination(PSD) of the QDC to the capabilities of the Jefferson Lab designed FADC. To obtain these results we set up a cosmic telescope, consisting of two scintillator paddles coupled with Photomultiplier tubes(PMT) to detect a high energy source of cosmic rays entering the Earth's atmosphere. The amplification of that pulse through the PMT is sent through a series of modules in addition to each respective module in question. The TDC gives us timing information, the QDC gives us energy information, while the FADC gives us both. After extracting our data and analyzing the outcomes, we found that the TDC has a better timing resolution and the QDC is better for PSD. From these findings we have found that the FADC is more reliable for a middle range of voltage, where as, the TDC and QDC have a larger range of accuracy. Each is more useful depending on the experiment. These results aid in the understanding of data analysis and will help experimentalists decipher what instrumentation is more equipped to conduct their experiment. The FADC's greatest contribution is that it can perform the same analysis as the TDC and the QDC, however, depending on the implementation it is important to decide whether that improvement outweighs the constraints.

## ABSTRACT

CEBAF 200kV Electron Gun Upgrade. ELLIOTT G. HOLLIDAY (North Carolina State University, Raleigh, NC 27607) CARLOS HERNANDEZ-GARCIA (Thomas Jefferson National Accelerator Facility, Newport News, VA 23606).

At Jefferson Lab, electrons are accelerated to near the speed of light using the Continuous Electron Beam Accelerator Facility (CEBAF). The electron beam is generated using an electron gun composed of a highly polarized GaAs/GaAsP superlattice photocathode with an operating voltage of 130kV in an ultra-high vacuum with an internal pressure of approximately  $10^{-12}$  torr. The electron gun is geometrically designed in such a way to limit the electric field below 10 MV/m at every point in the gun. Our objective is to construct and install an upgraded electron gun capable of running at 200kV in an ultra-high vacuum with zero field emission. We started the design of the gun by focusing on a specific geometry of the electrode to prevent high voltage cable breakdown. We went through a multi-step vacuum creation process that included three different types of pumping, a bake at 250° C, and the activation of the non-evaporable getters (NEGs). Afterwards, we did a high voltage conditioning of the gun where we slowly raised the voltage until we no longer saw electron field emission. Using the vacuum protocols, we achieved a vacuum of  $10^{-11}$  torr, which is reasonably acceptable, but not quite the desired value. During our high voltage conditioning, we saw slight field emission around the operating voltage of 200 kV, making the gun unfit for installation into CEBAF. This can be improved with further conditioning at higher voltages, but due to the limits of our power supply, we did not feel we had adequate head room to continue voltage conditioning. With this upgraded gun, we can give the accelerator higher beam quality and extended photocathode lifetime.

## ABSTRACT

Modified M20 Beam Position Monitor Testing. JESSICA KOROS (Florida State University, Tallahassee, FL 32306) JOHN MUSSON (Thomas Jefferson National Accelerator Facility, Newport News, VA 23606).

Beam position monitors (BPMs) are used throughout the Continuous Electron Beam Accelerator Facility (CEBAF) at Jefferson Lab (JLab) to measure lateral beam position. Two pairs of modified M20s, a model of BPM, are being evaluated for installation into the CEBAF injector. The BPMs were coated with a Non-Evaporable Getter (NEG) to aid in pumping H<sub>2</sub> and O<sub>2</sub> at the electron gun, as an ultra-high vacuum is required to protect the gun and to avoid scattering the nonrelativistic beam. This beam has a greater diameter than the relativistic beam in the main accelerator, allowing extraction of a second moment, which gives information about beam profile and emittance. The purpose of this project is to determine the effects of NEG coating on the M20s and to extract second moment information from beam models on the Goubau Line (G-Line). Using the G-Line, scans of the M20s were taken before and after NEG coating. Each scan produced an electrical field map, which characterizes properties of the BPM, including scale factors, coupling, and nonlinear regions. Second moments were calculated using superposition of previous scan data, and verified by taking a scan using a flattened wire or ribbon. Results show that the M20s responded well to NEG and that measurement of second moments is possible. This is the first time a NEG coated BPM has been used at JLab, as well as the first time BPMs have been used to measure beam profile and emittance in CEBAF. The results of this project show the success of these new methods. Once the M20s have been installed, they will enhance gun vacuum and enable monitoring of the shape and trajectory of the beam as it exits the electron gun to ensure good beam quality for experiments.

## ABSTRACT

Meson Loop Contributions to Nucleon Properties. RIDGE LIU (Rice University, Houston, TX 77005) WALLY MELNITCHOUK (Thomas Jefferson National Accelerator Facility, Newport News, VA 23606).

The structure of a nucleon (proton or neutron) consists of three valence quarks and a sea of quark-antiquark pairs arising from quantum fluctuations. An asymmetry has been observed between the parton distribution functions (PDFs) of the antiup and antidown quarks as well as between those of the strange and antistrange quarks in a nucleon. One possible explanation for the asymmetries is the effect of meson loop diagrams on the 3-valence quark structure of the nucleon, which arises from the chiral (left- vs. right-handed) symmetry of the underlying Quantum Chromodynamics (QCD) theory. This effect is quantifiable through splitting functions which describe ways a photon probe can interact with a nucleon. The focus of this study is to calculate the effect of one-meson-loop diagrams on the self-energy of a nucleon and nucleon to meson + baryon splitting functions using dimensional regularization (DR), a method for regulating divergent integrals. For both the self-energy and splitting function calculations, we evaluate the integral using DR and various renormalization schemes. We perform multiple checks on the calculation, including finding the leading nonanalytic behavior of the self-energy and splitting functions and comparing against published results. Here we present expressions for the self-energy and splitting functions calculated using DR. We also show the consistency of the calculations of the self-energy using DR with other regularization methods. We also. In contrast to other regularization methods such as high-momentum cutoff, dimensional regularization has the advantage of being manifestly covariant, i.e. respecting Lorentz invariance. The expression for the splitting function will allow for quantifying the magnitude of the meson loop corrections to the PDFs, en route to explaining the aforementioned observed asymmetries.

## **ABSTRACT**

Building a Test Stand to Study Timing & Pulse Shape Discrimination with TDC, QDC, and F250 FADC. TYLER MILKERIS-ZELLAR (University of West Florida, Pensacola, FL 32514) BRAD SAWATZKY (Thomas Jefferson National Accelerator Facility, Newport News, VA 23606).

The F250 Flash Analog to Digital Converter (FADC) is a relatively new module used in Data Acquisition Systems (DAQ) here at Jefferson Lab. The F250 FADC is meant to replace or supplement older DAQ modules like Time to Digital Converters (TDCs) and Charge Analog to Digital Converters (QDCs). The TDC has a certain intrinsic timing resolution and the QDC can integrate a pulse's charge, a feature which can also be used for particle identification between photons and neutrons using pulse shape discrimination (PSD). The focus of this project is developing a test stand to study timing and PSD performance of legacy modules TDC and QDC, and the new F250 FADC. A cosmic telescope was used to extract timing resolution from the TDC and FADC. Through PSD with the QDC and FADC, using a BC505 liquid scintillator, we plan to identify photons and neutrons from an americium-beryllium (AmBe) source. It was found that the TDC's timing resolution in the system was better than the FADC. Through PSD, it was found that the FADC allows for flexible data analysis compared to the QDC. The results indicate that the TDC provides a more accurate measurement of timing resolution than the FADC. This improvement allows for a clear distinction of what module to use when wanting precision of measurement in a DAQ for a cosmic ray telescope. With the results found we can conclude that the TDC is capable of extracting a timing resolution more precisely than the F250 FADC making the TDC the module to use. When comparing the QDC to the F250 FADC, the FADC compacts the use of two modules into one, making for a more desirable module.

## Abstract

Harmonic Kicker RF Cavity for the Jefferson Lab Electron-Ion Collider (JLEIC) EM Simulation, Modification, and Measurements SARAH OVERSTREET (Guilford College, Greensboro, NC 27410) DR. HAIPENG WANG (Thomas Jefferson National Accelerator Facility, Newport News, VA 23606).

An important step in the conceptual design for the future Jefferson Lab Electron-Ion Collider (JLEIC) is the development of supporting technologies for the Energy Recovery Linac (ERL) Electron Cooling Facility. The Harmonic Radiofrequency (RF) kicker cavity is one such device that is responsible for switching electron bunches in and out of the Circulator Cooling Ring (CCR) from and to the ERL, which is a critical part of the ion cooling process. Last year, a half scale prototype of the JLEIC harmonic RF kicker model was designed with resonant frequencies to support the summation of 5 odd harmonics (95.26 MHz, 285.78 MHz, 476.30 MHz, 666.82 MHz, and 857.35 MHz); however, the asymmetry of the kicker cavity gives rise to multipole components of the electric field at the electron-beam axis of the cavity. Previous attempts to symmetrize the electric field of this asymmetrical RF cavity have been unsuccessful. The aim of this study is to modify the existing prototype for a uniform electric field across the beam pathway so that the electron bunches will experience nearly zero beam current loading. In addition to this, we have driven the unmodified cavity with the harmonic sum and used the wire stretching method for an analysis of the multipole electric field components.

## ABSTRACT

Global QCD Analysis of the Nucleon Tensor Charge with Lattice QCD Constraints. HARVEY F. SHOWS III (Louisiana State University, Baton Rouge, LA 70803), NOBUO SATO, WALLY MELNITCHOUK (Thomas Jefferson National Accelerator Facility, Newport News, VA 23606).

By studying the parton distribution functions (PDFs) of a nucleon, we probe the partonic scale of nature, exploring what it means to be a nucleon. In this study, we are interested in the transversity PDF—the least studied of the three collinear PDFs. By conducting a global analysis on experimental data from semi-inclusive deep inelastic scattering (SIDIS), as well as single-inclusive  $e^+e^-$  annihilation (SIA), we extract the fit parameters needed to describe the transverse moment dependent (TMD) transversity PDF, as well as the Collins fragmentation function. Once the collinear transversity PDF is obtained by integrating the extracted TMD PDF, we wish to resolve discrepancies between lattice QCD calculations and phenomenological extractions of the tensor charge from data. Here we show our results for the transversity distribution and tensor charge. Using our method of iterative Monte Carlo, we now have a more robust understanding of the transversity PDF. With these results we are able to progress in our understanding of TMD PDFs, as well as testify to the efficacy of current lattice QCD calculations.

## ABSTRACT

Geometry Tagging of Heavy Ions JAMES STUKES ( Morehouse College, Atlanta, GA 30314)VASILIIY MOROZOV( Thomas Jefferson National Accelerator Facility, Newport News, VA 23606).

Jefferson lab is proposing the construction of an Electron Ion Collider (JLEIC) that will be used to study the propagation of partons produced in nuclear matter and to search for evidence of parton saturation at low longitudinal momentum fraction  $x$ . By using geometry tagging we can enhance measurements made by particle detectors in JLEIC. Geometry Tagging is an analysis technique that uses information from the breakup of a collision to categorize the collision's geometry. This technique allows us to select event samples in a way that we can control the geometry of collision. We first focused on measuring the production of forward neutrons and then demonstrated that resolution can be improved if other forward fragments are observed. The data file used for analysis was simulated and produced in BeAGLE with information on 100,000 collision events. Using the ROOT framework we were able to produce graphs relating to the multiplicity of fragments produced and the geometric parameters of the collision. The results show that the use of a combination of neutrons and other forward fragments produced may have an advantage in terms of resolution over focusing on just neutrons. At lower multiplicity cuts (in the range of  $10^{-4}$ ) the design including neutrons and other forward fragments had a higher average distance traveled in the nucleus by 1-2 fm. This increase in distance shows the merits of including other forward fragments in the detection process.

