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

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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

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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 < I 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.

Seperating the Spin States of a Free Electron Beam

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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

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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 onehundreth 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.