EPAC08 ABSTRACTS

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Ionization Cooling and Muon Colliders

Recent developments in the field of muon cooling are reviewed. A view of the impact of new cooling concepts on the overall design of muon colliders are included, as well as an outlook to experimental verification of muon cooling.

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Funding Agency:

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Primary Classification: 3: Linear Colliders, Lepton Accelerators and New Acceleration Techniques

Sub-Classification: A09 - Muon Accelerators and Neutrino Factories

Design Studies of Magnet Systems for Muon Helical Cooling Channels

Helical cooling channels consisting of a magnet system with superimposed solenoid and helical dipole and quadrupole fields, and a pressurized gas absorber in the aperture promise high efficiency in providing 6D muon beam cooling for a future Muon Collider and some other applications. Two alternative designs of magnet system for the helical cooling channel are being investigated at the present time. The first one is based on a straight large aperture solenoid with helical dipole and quadrupole coils. The other one is based on a spiral solenoid which generates the main solenoid field and the helical dipole and quadrupole components. Both concepts have been developed and compared for the MANX experiment. In this paper we continue design studies and comparison of these two concepts for the high field sections of a helical cooling channel. The results of magnetic and mechanical analysis as well as the superconductor choice and specifications will be presented and discussed.

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Type of Presentation: Oral or Poster

Primary Classification: 7: Accelerator Technology Main Systems

Sub-Classification: T10 - Superconducting Magnets

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Incorporating RF Into a Muon Helical Cooling Channel

A helical cooling channel (HCC) consisting of a pressurized gas absorber imbedded in a magnetic channel that provides solenoidal, helical dipole and helical quadrupole fields has shown considerable promise in providing six-dimensional cooling for muon beams. The energy lost by muons traversing the gas absorber needs to be replaced by inserting RF cavities into the lattice. Replacing the substantial muon energy losses using RF cavities with reasonable gradients will require a significant fraction of the channel length be devoted to RF. However, to provide the maximum phase space cooling and minimal muon losses, the helical channel should have a short period and length. In this paper we shall examine three approaches to include RF cavities into the HCC lattice: (1) Use higher frequency cavities that can be placed inside the magnetic channel, (2) Interleave cavities between magnetic coil rings, and (3) Place banks of RF cavities between segments of HCC channels. Each of these approaches has positive and negative features that need to be evaluated in selecting the proper concept for including RF into the HCC system.

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Status of the MANX Muon Cooling Experiment

MANX is an experiment to prove that effective six-dimensional (6D) muon beam cooling can be achieved a Helical Cooling Channel (HCC) using ionization-cooling with helical and solenoidal magnets in a novel configuration. The aim is to demonstrate that 6D muon beam cooling is understood well enough to plan intense neutrino factories and high-luminosity muon colliders. The experiment consists of the HCC magnets that envelop a liquid helium energy absorber, upstream and downstream instrumentation to measure the particle or beam parameters before and after cooling, and emittance matching sections between the detectors and the HCC. Studies are presented of the effects of detector resolution and magnetic field errors on the beam cooling measurements.

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Magnets for the MANX 6-D Muon Cooling Demonstration Experiment

MANX is a 6-dimensional muon ionization-cooling experiment that has been proposed to Fermilab to demonstrate the use of a helical cooling channel (HCC) for muon beam emittance reduction for future muon colliders and neutrino factories. The HCC for MANX has solenoidal, helical dipole, and helical quadrupole magnetic components, which diminish as the beam loses energy as it slows down in the liquid helium absorber inside the magnet. The proposed magnet system design is comprised of coil rings positioned along a helical path, which will provide the desired solenoidal and helical dipole and quadrupole fields. Additional magnets that provide emittance matching between the HCC and the upstream and downstream spectrometers are also described. The results of a G4Beamline simulation of the beam cooling behavior of the magnet and absorber system will be presented.

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4-Coil Superconducting Helical Solenoid Model for Muon Beam Cooling

Novel configurations of superconducting magnets for helical muon beam cooling channels and demonstration experiments are being designed at Fermilab. The magnet system for helical cooling channels have to generate longitudinal solenoidal and transverse helical dipole and helical quadrupole fields. This paper discusses the Helical Solenoid model design and manufacturing of a 0.6 m diameter, 4-coil solenoid prototype to prove the design concept, fabrication technology, and the magnet system performance. Results of magnetic and mechanical designs with the 3D analysis by TOSCA, ANSYS and COMSOL will be presented. The model quench performance and the test setup in the FNAL Vertical Magnet Test Facility cryostat will be discussed.

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High Field Superconductor for Muon Cooling

High temperature superconductors (HTS) have been shown to carry significant current density in the presence of extremely high magnetic fields when operated at low temperature. The successful design of magnets needed for high energy physics applications using such high field superconductor (HFS) depends critically on the detailed wire or tape parameters which are still under development and not yet well-defined. In the project reported here, we are developing HFS for accelerator use by concentrating on the design of an innovative magnet that will have a useful role in muon beam cooling. Measurements of available materials and a conceptual design of a high field solenoid using YBCO HFS conductor are being analyzed with the goal of providing useful guidance to superconductor manufacturers for materials well suited to accelerator applications.

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Multi-purpose Fiber Optic Sensors for HTS Magnets

Magnets using new high temperature superconductor (HTS) materials are showing great promise for high magnetic field and/or radiation environment applications such as particle accelerators, NMR, and the plasma-confinement systems for fusion reactors. The development and operation of these magnets is limited, however, because appropriate sensors and diagnostic systems are not yet available to monitor the manufacturing and operational processes that dictate success. Optical fibers are being developed to be imbedded within the HTS magnets to monitor strain, temperature and irradiation, and to detect quenches. In the case of Bi2212, the fiber will be used as a heat treatment process monitor to ensure that the entire magnet has reached thermal equilibrium. Real-time measurements will aid the development of high-field magnets that are subject to large Lorentz forces and allow the effective detection of quenches so that the stored energy of operating magnets can be extracted and/or dissipated without damaging the magnet.

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Advances in Parametric-resonance Ionization Cooling

Parametric-resonance ionization cooling (PIC) is a muon-cooling technique that is useful for low-emittance muon colliders. This method requires a well-tuned focusing channel that is free of chromatic and spherical aberrations. The dispersion function of the channel must be large where the correction magnets are placed for aberration control but small and non-zero where the ionization cooling beryllium wedges are located to provide emittance exchange to maintain small momentum spread. In order to be of practical use in a muon collider, it also necessary that the focusing channel be as short as possible to minimize muon loss due to decay. A compact PIC focusing channel is described in which new magnet concepts are used to generate the required lattice functions.

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Aberration-free Muon Transport Line for Extreme Ionization Cooling

Once the normalized transverse emittances of a muon beam have been cooled to some hundreds of microns, new techniques such as Parametric-resonance Ionization Cooling and Reverse Emittance Exchange can be used to focus the beam very tightly on beryllium energy absorbers for further transverse emittance reduction. The transport lines for these techniques have stringent requirements for the betatron tunes so that resonance conditions are properly controlled and for the dispersion function so that the longitudinal emittance can be controlled by emittance exchange using wedge-shaped absorbers. The extreme angular divergence of the beam at the absorbers implies large beam extension between the absorbers such that these techniques are very sensitive to chromatic and spherical aberrations. In this work we describe general and specific solutions to the problem of compensating these aberrations for these new muon cooling channels.

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Sub-Classification: A14

Isochronous Pion Decay channel for Enhanced Muon Capture

Intense muon beams have many potential commercial and scientific applications, ranging from low-energy investigations of the basic properties of matter to high-energy muon colliders. However, muons originate from a tertiary process that produces a diffuse swarm of muons. To make useful beams, the swarm must be rapidly cooled before the muons decay. A promising new concept for the collection and cooling of muon beams to increase their intensity and reduce their emittances is being investigated, namely, the use of a nearly isochronous helical transport channel (HTC) to facilitate capture of the muons into RF bunches. Such a distribution could be cooled quickly and coalesced into a single bunch to optimize the luminosity of a muon collider. We describe the HTC as well as methods to integrate such a subsystem into the rest of a muon collection and cooling system.

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Intense Stopping Muon Beams

The study of rare processes using stopping muon beams provides access to new physics that cannot be addressed at energy frontier machines. The flux of muons into a small stopping target is limited by the kinematics of the production process and by stochastic processes in the material used to slow the particles. Innovative muon beam cooling techniques are being applied to the design of stopping muon beams in order to increase the event rates in such experiments. Such intense stopping beams will also aid the development of applications such as muon spin resonance and muon-catalyzed fusion.

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Recirculating Linear Muon Accelerators with Ramped Quadrupoles

Neutrino Factories and Muon Colliders require rapid acceleration of short-lived muons to multi-GeV and TeV energies. A Recirculating Linear Accelerator (RLA) that uses a single Linac and teardrop return arcs can provide exceptionally fast and economical acceleration to the extent that the focusing range of the RLA quadrupoles allows each muon to pass several times through each high-gradient cavity. A new concept of rapidly changing the strength of the RLA focusing quadrupoles as the muons gain energy is being developed to increase the number of passes that each muon will make in the RF cavities, leading to greater cost effectiveness. We are developing the optics and technical requirements for RLA designs, using RF cavities capable of simultaneous acceleration of both μ^+ and μ^- species, with pulsed Linac quadrupoles to allow the maximum number of passes.

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Primary Classification: 3: Linear Colliders, Lepton Accelerators and New Acceleration Techniques

Sub-Classification: A09 - Muon Accelerators and Neutrino Factories

Flexible Momentum Compaction Return Arcs for RLAs

Neutrino Factories and Muon Colliders require rapid acceleration of short-lived muons to multi-GeV and TeV energies. A Recirculating Linear Accelerator (RLA) that uses a single Linac and teardrop return arcs can provide exceptionally fast and economical acceleration to the extent that the focusing range of the RLA quadrupoles allows each muon to pass several times through each high-gradient cavity and the cost of the return arcs is appropriate. Flexible Momentum Compaction (FMC) lattice designs for the teardrop return arcs provide sufficient momentum acceptance to allow multiple passes of each sign of muon in one string of magnets to improve cost-effectiveness.

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Funding Agency:

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Sub-Classification: A09 - Muon Accelerators and Neutrino Factories

Plasma Lenses for Muon and Neutrino beams

The plasma lens is examined as an alternate to focusing horns and solenoids for use in a neutrino or muon beam facility. The plasma lens concept is based on a combined high current lens/target configuration. The current is fed at electrodes located upstream and downstream form the target where pion capturing is needed. The current flows primarily in the plasma, which has a lower resistivity than the target. A second plasma lens section, with an additional current feed, follows the target to provide shaping of the plasma for optimum focusing. The plasma lens is immersed in an additional solenoidal magnetic field to facilitate the plasma stability. The geometry of the plasma is shaped to provide optimal pion capture. Simulations of this plasma lens system have shown a 25% higher neutrino production than the horn system. Plasma lenses have additional advantages: larger axial currents than horns, minimal neutrino contamination during antineutrino running, and negligible pion absorption or scattering. Results from particle simulations using plasma lens will be presented.

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Funding Agency:
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Sub-Classification: T02

Work function dependence of RF Breakdown in Pressurized RF Cavities

Previous studies of RF breakdown in a cavity pressurized with dense hydrogen gas have indicated that breakdown probability is proportional to a high power of the surface electromagnetic field. This behavior is similar to the Fowler-Nordheim description of electron emission from a cold cathode and it implies that breakdown is a quantum mechanical effect that is characterized by the work function of the cavity metal. We describe our present efforts to measure the distributions of work functions at the nanoscale level on the surfaces of the electrodes used in breakdown studies and to understand how the RF conditioning process affects them.

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Sub-Classification: T06 - Room Temperature RF

Compact, Tunable RF Cavities

New developments in the design of fixed-field alternating gradient (FFAG) synchrotrons have sparked interest in their use as rapid-cycling, high intensity accelerators of ions, protons, muons, and electrons. Potential applications include proton drivers for neutron or muon production, rapid muon accelerators, electron accelerators for synchrotron light sources, and medical accelerators of protons and light ions for cancer therapy. Compact RF cavities that tune rapidly over various frequency ranges are needed to provide the acceleration in FFAG lattices. An innovative design of a compact RF cavity that uses orthogonally biased ferrite for fast frequency tuning and liquid dielectric to adjust the frequency range is being developed using physical prototypes and computer models.

Authors:

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Funding Agency:

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Sub-Classification: T06 - Room Temperature RF

G4Beamline Particle Tracking in Matter-Dominated Beam Lines

Most computer programs that calculate the trajectories of particles in accelerators assume that the particles travel in an evacuated chamber. The development of muon beams, which are needed for muon colliders and neutrino factories and are usually required to pass through matter, is limited by the lack of user-friendly numerical simulation codes that accurately calculate scattering and energy loss in matter. Geant4 is an internationally supported tracking toolkit that was developed to simulate particle interactions in large detectors for high energy physics experiments, and includes most of what is known about the interactions of particles and matter. Geant4 has been partially adapted in a program called G4beamline (G4BL) to develop muon beam line designs. We are continuing the development of G4BL to enhance its graphical user-interface and add other features to the program to facilitate its use by a larger set of beam line and accelerator developers.

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Funding Agency:

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Sub-Classification: A09 Muon Accelerators and Neutrino Factories

G4Beamline Program for Radiation Simulations

G4beamline, a program that is an interface to the Geant4 toolkit that we have developed to simulate accelerator beamlines, is being extended with a graphical user interface to quickly and efficiently model experimental equipment and its shielding in experimental halls. The program is flexible, user friendly, and requires no programming by users, so that even complex systems can be simulated quickly. This improved user interface is of much wider application than just the shielding simulations that are the focus of this project. As an initial application, G4beamline is being extended to provide the simulations that are needed to determine the radiation sources for the proposed experiments at Jefferson Laboratory so that shielding issues can be evaluated. Since the program already has the capabilities needed to simulate the transport of all known particles, including scattering, attenuation, interactions, and decays, the extension involves implementing a user-friendly graphical user interface for specifying the simulation, and creating general detector and shielding component models and interfacing them to existing Geant4 models of the experimental halls.

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Sub-Classification: T18 Radiation Monitoring and Safety

G4Beamline Simulations for Detector Development

In current research programs to develop radiation detection instruments, simplifying assumptions are frequently made in estimating the resolutions and efficiencies attainable by neutron and gamma-ray instruments. Monte Carlo programs (such as Geant4) are capable of realistically modeling such problems, but the technical details of setting up, running, and interpreting the required simulations are beyond the ability of all but the most expert researchers. G4beamline, a program that is an interface to the Geant4 toolkit for the simulation of accelerator beam lines, is being extended to model detectors and related systems needed for applications related to nuclear nonproliferation. The program is flexible, extremely user friendly, and requires no programming by users. Simulations of simple or complex detectors can be setup quickly and are accurately simulated using the power and accuracy of Geant4 for the transport of particles, including scattering, attenuation, interactions, and decays.

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Sub-Classification: T28 Subsystems, Technology and Components, other

Electron Accelerators For Cleaning Flue Gases and for Oil Liquefaction

High-power electron beams can be used to reduce the environmental impact of coal and oil-fired power generating plants by removing harmful materials from flue gases. This technology has been tested in the laboratory and at smaller industrial levels, but to make it economically attractive, the accelerator costs must be reduced and the efficiency must be increased for removing toxic components in low concentrations. We propose a simple electron accelerator with a wide beam to reduce costs. To remove toxic materials we propose a plasma reactor for desulfurization and selective catalytic reduction. The designs of 0.5 to 1.0 MeV accelerators with 20 to 100 kW average power are considered, along with the design of a plasma reactor for flue gas treatment. The design of a pilot facility for the oil industry is also presented.

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