COOL'15

Workshop on Beam Cooling and Related Topics

Sept. 28 - Oct. 2, 2015 • Jefferson Lab • Newport News, Virginia USA

Abstract Booklet

JSA Jefferson Lab

8:00-8:30 : Registration and Continental Breakfast

8:30-8:50: Welcome and Opening Comments

Workshop welcome and opening comments.

Andrew Hutton (Jefferson Lab)

8:50-9:20: Status and Perspectives of Cooling Methods

The presentation will summarize the established cooling methods. Highlights of the achievements of past and existing facilities will be reviewed. Current developments in the field of beam cooling and the requirements and plans for cooling in proposed accelerator projects will be discussed.

Markus Steck (GSI)

09:20-9:50: Overview of Muon Cooling

Muon cooling techniques will be surveyed, along with a concise overview of the relevant R&D that has been pursued.

Dan Kaplan (Illinois Institute of Technology)

09:50-10:20: High Luminosity Electron-Proton (Ion) Colliders

At Budker INP, we consider now possibility to reach interesting enough cooling times for 100 GeV range proton (ion) beams, using single pass electron beam with parameters, which are now in operation for Novosibirsk free electron lasers. To reach good electron cooling for high energy protons, it is necessary to get effective electron beam angular spread smaller than angular spread in proton beam. This requires to immerse electron beam in co-linear longitudinal magnetic field. It is assumed – 'large' proton amplitudes would be cooled with stochastic cooling, but the small amplitudes core would be cooled with appropriate electron beam, produced similar way as for our FEL. For higher charge ions to reach acceptable cooling rate is even easier.

Alexander Skrinsky (BINP SB RAS)

10:40-11:10: Performance of the 2 MeV Electron Cooler at COSY

Vsevolod Kamerdzhiev (FZJ)

The 2 MeV electron cooler is operated in the COSY ring since 2013. So far electron beam energy up to 1.5 MeV was demonstrated. Dedicated electron cooling studies with proton beams up to 1.66 GeV kinetic energy and electron beam current up to 0.9 A were carried out. A reduction of proton beam emittance by one order of magnitude within a few hundred seconds was observed. Overview of HV and electron beam commissioning activities is presented. Electron cooling results are discussed.

11:10-11:40: Experimental Observation of Longitudinal Electron Cooling of DC and Bunched Proton Beam at 2425 MeV/c at COSY

Vladimir Reva (BINP SB RAS)

The 2 MeV electron cooling system for COSY-Julich started operation in 2013 years. The cooling process was observed in the wide energy range of the electron beam from 100 keV to 908 keV. Vertical, horizontal and longitudinal cooling was tested at bunched and continuous beams. The cooler was operated with electron current up to 0.9 A. This report deals with the description of the experimental observation of longitudinal electron cooling of DC and bunched proton beam at 2425 MeV/c at COSY.

11:40-12:10: Low Energy RHIC Electron Cooling (LEReC) Project

Alexei Fedotov (BNL)

An electron cooler is presently under construction to improve the luminosity of the Relativistic Heavy Ion Collider (RHIC) for heavy ion beam energies below 10 GeV/nucleon. Required electron beam and its acceleration (up to 2 MeV in Phase-I and up to 5 MeV in Phase-II) are provided by the photoemission electron gun and the RF linear accelerator. As a result, cooling will be accomplished by using bunched electron beams produced by high-brightness high-current electron linear accelerator. In addition, this will be the first electron cooling applied directly in a collider. In this presentation we describe accelerator physics requirements, design considerations and parameters, as well as associated challenges of such a low-energy RHIC electron cooler (LEReC).

12:10-12:30: The ELENA Electron Cooler

Lars Joergensen (CERN)

The ELENA project (Extra Low ENergy Antiprtons) at CERN is nearing completion. One of the crucial components of the this new decelerator ring will be the associated electron cooler. With a final antiproton energy in ELENA of 100 keV the electron cooler will be working at a very low electron energy of just 55 eV. We will present the design consideratiosn andproduction status of the cooler.

13:30-14:00: Update on the RHIC Stochastic Cooling

Mike Brennan (BNL)

The bunched beam Stochastic Cooling system for RHIC will be described. Special hardware components such as, kickers, signal processing electronics, and a microwave link will be discussed. Results of cooling heavy ion beams during physics stores will be presented.

14:00-14:30: Stochastic Cooling of Heavy Ions in the HESR

Rolf Stassen (FZJ)

Due to the modularized start version (MSV) of the FAIR project with the postponed NESR, the HESR (High Energy Storage Ring) became very attractive for experiments with heavy ions. Although the HESR is optimized for the storage of antiprotons it is also well suited for heavy-ion beams with slightly changes in the optics. Within the MSV only stochastic cooling and no e-cooling will be available, but even the main 2-4 GHz stochastic cooling system will be capable to fulfill the beam requirements for heavy ions. Most critical parts of the active elements are the high power amplifiers. The stochastic cooling amplifiers for the HESR will be based on new GaN devices. Nonlinearities of these devices necessitate a dedicated analysis for use in stochastic cooling systems.

14:30-14:50 : Stochastic Cooling System for HESR - Theoretical and Simulation Studies

Hans Stockhorst (FZJ)

The High-Energy Storage Ring (HESR) is part of the upcoming International Facility for Antiproton and Ion Research (FAIR) at GSI in Darmstadt. The HESR dedicates to the field of high-energy antiproton physics to explore the research areas of charmonium spectroscopy, hadronic structure, and quark-gluon dynamics with high-quality beams over a broad momentum range from 1.5 to 15 GeV/c. The facility provides the combination of powerful phase-space cooled antiproton beams and internal Pellet or gas jet targets to achieve the requirements of the experiment PANDA in terms of beam quality and luminosity. Recently, the feasibility of the HESR has been investigated for the application of cooled heavy ion beams with the special emphasis on the experimental program of the SPARC collaboration at FAIR. In this contribution an outline of the Fokker-Planck approach and particle tracking for momentum cooling assisted by a barrier bucket cavity with an internal target is given. A comparison of the filter and filter-less TOF cooling techniques including beam feedback is presented. Simulation and experimental studies at COSY to verify the predictions of the cooling theory complete the contribution.

14:50-15:20: Stochastic Cooling Developments for the Collector Ring at FAIR

Christina Dimopoulou (GSI)

A Status report on the ongoing developments for the demanding stochastic cooling system of the Collector Ring is given. The system operates in the frequency band 1-2 GHz, it has to provide fast 3D cooling of antiproton, rare isotope and stable heavy ion beams. The main challenges are (i) the cooling of antiprotons by means of cryogenic movable pick-up electrodes and (ii) the fast two-stage cooling (precooling by the Palmer method, followed by the notch filter method) of the hot rare isotope beams. Progress in designing, testing and integrating the hardware is discussed.

15:40-16:10: The Muon Accelerator Program: R&D Towards Future Neutrino Factory and Lepton Collider Capabilities

Mark Palmer (Fermilab)

Muon accelerators offer unique potential for high energy physics applications. Muon storage rings can provide pure, well-characterized and intense neutrino beams for short- and long baseline neutrino-oscillation studies – thus providing unmatched measurement precision for key parameters such as the CP-violating phase and a sensitive probe for new physics. With the muon mass being 200 times that of the electron, muon beams are not subject to the synchrotron radiation and beamstrahlung limits imposed on electron-positron colliders. Thus muon beams can be accelerated to TeV-scale energies and stored in collider rings where the beams can interact for many revolutions. For center-of-mass energies in the multi-TeV range, muon colliders provide the most power efficient route to providing a high luminosity lepton collider. The R&D effort to develop these capabilities by the Muon Accelerator Program, the current status of the concepts, and future possibilities for this research are described.

16:10-16:40: Overview of Muon Colliders

Bob Palmer (BNL)

16:40-17:10: Current Status of Electron and RI Collision Project at RIKEN

Masanori Wakasugi (RIKEN)

The SCRIT electron scattering facility has been constructed at RIKEN RI beam factory. This is aimed at determination of charge density distribution for short-lived unstable nuclei. The facility consists of an electron accelerator (RTM), an electron storage ring (SR2) equipped with the SCRIT device, an ISOL system (ERIS), and a high-resolution magnetic spectrometer (WiSES). Radio-active isotope ions, which are produced at the ERIS, are trapped in the SCRIT device and collide with the accumulated electron beam in SR2. The angular distribution of elastically scattered electrons is measured using the WiSES detector. The facility is now under comprehensive test using stable isotopes, and the preparation of experiment for unstable nuclei is now in process. Current status of the facility and recent test experiments are presented.

17:10-19:00 : Poster Session I and Workshop Reception

MOPF01 : Final Cooling for a High Energy High Luminosity Collider

David Neuffer (Fermilab)

The final cooling system for a high-energy high-luminosity muon collider requires reduction of the transverse emittance by an order of magnitude to ≈0.00003 m (rms, N), while allowing longitudinal emittance increase to ≈0.1m. In an initial approach, this is obtained by transverse cooling of low-energy muons within a sequence of high field solenoids with low-frequency rf systems. Since the final cooling steps are actually emittance exchange, much of this transformation can be obtained by thick wedge absorbers at matched parameters. Other variations using quad-based cooling channels, transverse beam slicing and round to flat transforms can be used. in x-y, with transverse slicing and longitudinal recombination are discussed. Development of lowest emittance cooling with final exchange is discussed.

MOPF02 : The Green Energy Turbine as Turbo Generator for Powering the HV-Solenoids at a Relativistic Electron Cooler

Andre Hofmann (HIM)

One challenge in the development of a relativistic electron cooler is the powering of components, e.g. HV-solenoids, which sit on different potentials within a high voltage vessel and need a floating power supply. Within a design study, BINP SB RAS Novosibirsk has proposed two possibilities to build a power supply in a modular way. The first proposal is to use two cascade transformers per module. One cascade transformer powers 22 small HV-solenoids; the second one should generate the acceleration/deceleration voltage. The cascade transformers are fed by a turbo generator, which is powered by a gas under high pressure which is generated outside of the vessel. The second possibility is to use two big HV-solenoids per module. In this proposal, the HV-solenoids are powered directly by a turbo generator. For both concepts, a suitable turbo generator is essential. A potential candidate for the turbo generator could be the Green Energy Turbine (GET) from the company DEPRAG, which works with dry air and delivers a power of 5 kW. At the Helmholtz-Institut Mainz two GETS are tested. After an introduction, we present our experience with the GET and give an overview of the further road map.

MOPF03 : Electron Lenses and Cooling for the Fermilab Integrable Optics Test Accelerator

Giulio Stancari (Fermilab)

Recently, the study of integrable Hamiltonian systems has led to nonlinear accelerator lattices with one or two transverse invariants and wide stable tune spreads. These lattices may drastically improve the performance of high-intensity machines, providing Landau damping to protect the beam from instabilities, while preserving dynamic aperture. The Integrable Optics Test Accelerator (IOTA) is being built at Fermilab to study these concepts with 150-MeV pencil electron beams (single-particle dynamics) and 2.5-MeV protons (dynamics with self fields). One way to obtain a nonlinear integrable lattice is by using the fields generated by a magnetically confined electron beam (electron lens) overlapping with the circulating beam. The required parameters are similar to the ones of existing devices. In addition, the electron lens will be used in cooling mode to control the brightness of the proton beam and to measure transverse profiles through recombination. More generally, it is of great interest to investigate whether nonlinear integrable optics allows electron coolers to exceed limitations set by both coherent or incoherent instabilities excited by space charge.

MOPF04 : 2D McMillan map for Accelerator Physics

Timofey Zolkin (Fermilab)

The McMillan lens is one of the most important concepts of 1D nonlinear integrable optics for accelerators, however, its generalization to higher dimensions is not trivial. We will discuss two possible extensions to 2D, namely, axially symmetric McMillan lens which is based on hollow electron lens, and, quasi-integrable map based on the McMillan magneto-static lens and properly tuned linear lattice. The beam dynamics in the first case resembles the electron cooling process and possibly the lens can be used as a cooling device by itself. The second one has very nontrivial phase-space structure due to strong sensitivity to initial conditions, which experimental study may be done with the use of very cold (in transverse dimensions) pencil-like beams. In addition we will discuss Smaller and Global Alignment Indexes techniques allowing to distinguish ordered motion from chaotic which is based on the Lyapunov stability analysis.

MOPF05 : A Cooling Storage Ring for an Electron-Ion Collider

James Gerity (Texas A&M University)

Electron cooling offers performance advantages to the design of an electron-ion collider. A first design of a 6 GeV/u storage ring for the cooling of ions in MEIC is presented, along with some remarks on the particulars of electron cooling in this ring.

MOPF06 : Electron Detection for a Sympatheticly Cooling Penning Trap

Brian Kootte (TRIUMF)

Nuclear masses serve as critical inputs in models of nucleosynthesis and provide insight into nuclear structure among other branches of physics. The TITAN facility at TRIUMF uses a precision Penning trap mass spectrometer to measure nuclear masses with precisions of 107 or better. Precision can be enhanced by charge breeding the ions before measurement. The charge breeding process increases the energy spread of the ions, thus decreasing the trapping efficiency in the precision Penning trap and therefore reducing the precision of mass measurements. A Cooler Penning Trap (CPET) is being developed to cool the Highly Charged Ion (HCI) bunch to < 1 eV/q before injection into the measurement Penning trap. The HCIs will be sympathetically cooled via a co-trapped plasma of electrons. Characterization of the trapped electron plasma has been done with CPET off the TITAN beamline. Recent work has focused on developing a strategy to effectively detect the trapped electron plasma without obstructing the passage of ions through the beamline as maintaining transmission efficiencies is paramount. The first offline tests demonstrate the ability to trap and detect more than 10^9 electrons.

MOPF07 : Final Muon Ionization Cooling Channel using Quadrupole Doublets for Strong Focusing

John Acosta (UMiss)

Considerable progress has been made in the design of muon ionization cooling for a collider. A 6D normalized emittance of 0.123 cubic mm has been achieved in simulation. However, the 6D emittance required by a high luminosity muon collider is 0.044 cubic mm. We explore a final cooling channel composed of quadrupole doublets limited to 14 Tesla. Flat beams formed by a skew quadrupole triplet are used. The low beta regions, as low as 5 mm, produced by the strong focusing quadrupoles are occupied by dense, low Z absorbers that cool the beam. Work is in progress to keep muons with different path lengths in phase with the RF located between cells and to modestly enlarge quadrupole admittance. Calculations and individual cell simulations indicate that the final cooling needed can be achieved. Full simulations are in progress. After cooling, emittance exchange in vacuum reduces the transverse emittance to 25 microns and lets the longitudinal emittance grow to 70 mm as needed by a collider. Septa slices a bunch into 17 parts; RF deflector cavities interleaved bunches into a 3.7 meter long train. Snap bunch coalescence combines the bunches into one in a 21 GeV ring in 55 microseconds.

MOPF08 : Secondary Electron Measurements at the HIM Electron Cooler Test Set-Up

Max-Wilhelm Bruker (HIM)

The planned advances in electron cooling technology aimed at improving the operation of future hadron storage rings include an increase in electron beam current and acceleration voltage. A test set-up has been built at Helmholtz-Insitut Mainz (HIM) to optimize the recuperation efficiency of such high-current beams in energy recovery operation, requiring a thorough understanding of their interaction with external electric and magnetic fields, such as those found in a Wien velocity filter. Beam diagnostics are carried out using a BPM and current-sensing scraper electrodes. At present, the set-up can be successfully operated at U=17 kV, I=600 mA, showing a relative secondary electron current of about 2e-4. We present the current state of the project and its objectives for the foreseeable future.

MOPF09 : Signals from a Beam Performing Betatron Oscillations Using an Electrostatic Electrode Model with Rectangular Boundaries

Fritz Nolden (GSI)

We present a novel electrostatic electrode model with rectangular boundaries. The fields are calculated using a conformal mapping. These fields are used to calculate the signal due to a relativistic beam. The response at harmonics of the revolution frequency and at the corresponding horizontal and vertical sidebands is given. The underlying nonlinear formalism is due to Bisognano and Leeman. The electrode geometry of the new stochastic cooling system at the CSRe ring at the IMP in Lanzhou is taken to derive the responses in the sum mode, the horizontal difference mode, and the vertical difference mode.

MOPF10 : Design Beam Diagnostic System for Optical Stochastic Cooling in IOTA Ring

Katsuya Yonehara (Fermilab)

Validation test of optical stochastic cooling (OSC) with 100 MeV electron beam is designed at IOTA ring at Fermilab. A beam diagnostic system for the test is discussed in this paper. The beam position and bunch length will be measured by using a standard button-pickup BPM; while the beam emittance will be measured by using a CCD-based synchrotron light detector. Especially, accurate time measurement is essential to carry out OSC experiments with a single particle. Desired time resolution is the order of 100 ps to study the cooling decrement in various lattice parameters. SiPM is an attractive solid-state device to detect a time domain synchrotron radiation photon. It can realize a fast rise time < 100 ps with a short time width 1-2 ns FWHM and its quantum efficiency is > 40 % at 420 nm. The beam instrumentation required to tune timing in the OSC insert is also discussed. It is based on the interference of radiation coming from the pickup and kicker undulators.

MOPF11 : First Tests and Status of the Cec Pop Experiment

Igor Pinayev (BNL)

The construction of the CeC PoP experimental set-up approach the final stage. In this paper we describe the status of the project and near term plans. The low power beam test results of the SRF gun will be also presented.

MOPF12 : N-body Code to Demonstrate Electron Cooling

Sumana Abeyratne (Northern Illinois University)

In the Electron Ion Collider (EIC), the collision between the electron beam and the proton, or heavy ion, beam results in emittance growth of the proton beam. Electron cooling, where an electron beam and the proton beam co-propagate, is the desired cooling method to cool or mitigate the emittance growth of the proton beam. The pre-booster, the larger booster, and the collider ring in EIC are the major components that require electron cooling. To study the cooling effect, we previously proposed Particles High order Adaptive Dynamics (PHAD) code that uses the Fast Multiple Method (FMM) to calculate the Coulomb interactions among charged particles. We further used the Strang splitting technique to improve the code's efficiency and used Picard iteration-based novel integrators to maintain very high accuracy. In this paper we explain how this code is used to treat relativistic particle collisions. We are able calculate the transverse emittances of protons and electrons in the cooling section while still maintaining high accuracy. This presentation will be an update on progress with the parallelization of the code and the current status of production runs.

MOPF13 : Ultra-Fast Harmonic Resonant Kicker Design for the MEIC Electron Circular Cooler Ring

Yulu Huang (IMP/CAS)

Electron cooling is essential for the proposed MEIC to attain low emittance and high luminosity. The present MEIC design utilizes bunched electron beam cooler ERL in the collider ring. To achieve a high electron beam current in the cooling channel but a low beam current in ERL, a circulator ring is adopted. The electron bunches will recirculate for 25 turns, thus the current in the ERL can be reduced by a factor of 25. Two ultra-fast kickers are required in this circulator ring, with a pulse width less than 2.1ns (1/476.3MHz) and a high repetition frequency of 19.052MHz (1/25 of 476.3MHz). Jefferson Lab started an LDRD proposal to develop such a kicker. Our approach is to generate a series harmonic modes with RF resonant cavities, electron bunches passing through the cavities will experience an integral effect of all the harmonic fields, thus every 25th bunch in the bunch train will be kicked while all the other bunches un-kicked. Here we present a design of a prototype with every 10th bunch kicked, using four Quarter Wave Resonator based cavities to generate 10 harmonic modes. Cavity structure ,tuner and coupler positions are optimized here.

MOPF14 : MEIC Electron Cooler Architecture and Beam Simulations

Fay Hannon (Jefferson Lab)

A discussion of the complexities in meeting the MEIC electron cooling beam specifications is presented. Simulations of various schemes are shown to evaluate the best architecture.

8:00-8:30 : Registration and Continental Breakfast

8:30-8:50: Status, Recent Results and Prospect of the International Muon Ionization Cooling Experiment (MICE)

Chris Rogers (STFC/RAL/ASTeC)

Muon accelerators have been proposed as a means to produce intense, high energy muon beams for particle physics. Designs call for beam cooling to provide suitable beams. Existing cooling schemes cannot operate on time scales that are competitive with the muon lifetime. Ionisation cooling has been proposed as a means to achieve sufficient cooling, but it has never been demonstrated practically. In the Muon Ionisation Cooling Experiment (MICE), based at the Rutherford Appleton Laboratory, ionisation cooling will be demonstrated. MICE Step IV is currently in progress and will be completed in 2016. Muons are brought onto an absorber, resulting in a reduction of momentum and hence reduction of normalised transverse emittance. The full Demonstration of Ionisation Cooling will take place in 2017. An extra magnet module and RF cavities will be installed, as in a cell of a cooling channel. This will enable demonstration of reduction of emittance and subsequent re-acceleration, both critical components for a realistic ionisation cooling channel.

8:50-9:20: Affordable, Scalable, and Convincing 6-d Muon Cooling Demonstrations

Rol Johnson (Muons)

The number of applications that could benefit from effective, affordable muon cooling include stopping muon beams for rare decay searches and spin resonance, intermediate energy beams for neutrino factories and cargo scanning, and muon colliders for HIggs factories and the energy frontier. The simple ionization cooling equation implies that if you have a low-Z energy absorber in a strong magnetic field, sufficient RF to contain the beam and replace the lost energy, and some mechanism for emittance exchange, you can achieve low 6-d emittance down to the limit implied by multiple scattering. The first cooling simulations that were based on a ring were exciting and encouraging. Unfortunately, injection difficulties, beam loading of RF cavities and energy absorbers, and the need to modify cooling parameters as the beam cools have led us away from a ring towards a cooling channel. An effective demonstration experiment must show that the final muon beam parameters to achieve the required luminosity can be achieved at an acceptable cost. We discuss the possibility that a demonstration experiment is a section of a practical, high performance cooling channel.

9:20-9:50: Study of Helical Cooling Channel for Intense Muon Source

Katsuya Yonehara (Fermilab)

Linear beam dynamics of muons in a helical cooling channel is non-trivial. Betatron oscillation in the channel is induced by coupling of motions in xyz-planes. As a result, the analytic eigen values are very complicated. The cooling decrements are controlled by tuning coupling strength. The helical dynamic parameters are translated into the conventional accelerator physics term. Non-linear dynamics in the helical channel is studied by using the conventional accelerator technique. The beam-plasma interaction in a high-pressure hydrogen gas-filled RF cavity is a new physics process and important to design the cooling channel. Machine development of helical beam elements is also shown in this presentation.

9:50-10:10: Progress on Parametric-resonance Ionization Cooling

Vasiliy Morozov (Jefferson Lab)

Proposed next-generation muon collider will require major technical advances to achieve the rapid muon beam cooling requirements. Parametric-resonance Ionization Cooling (PIC) is proposed as the final 6D cooling stage of a high-luminosity muon collider. In PIC, a half-integer parametric resonance causes strong focusing of a muon beam at appropriately placed energy absorbers while ionization cooling limits the beam's angular spread. Combining muon ionization cooling with parametric resonant dynamics in this way should then allow much smaller final transverse muon beam sizes than conventional ionization cooling alone. One of the PIC challenges is compensation of beam aberrations over a sufficiently wide parameter range while maintaining the dynamical stability with correlated behavior of the horizontal and vertical betatron motion and dispersion. We explore use of a coupling resonance to reduce the dimensionality of the problem and to shift the dynamics away from non-linear resonances. PIC simulations are presented.

10:30-11:00: First Operation of the Heidelberg Cryogenic Storage Ring CSR for Low-Energy Collision Measurements With Molecular Ion Beams

Andreas Wolf (MPI-K)

The cryogenic storage ring CSR has performed its first cryogenic beamtime in the first half of 2015. All vacuum chambers and ion optics of the electrostatic ring of 35 m circumference were cooled well below 10 K. Positive and negative ion beams were stored with energies of 60 keV at storage time constants that exceeded 2000 s in some cases. In the extremely low residual gas pressures, products of collisional beam loss reactions became in many cases unobservable. Laser-induced photodetachment was observed from various atomic and molecular ions including O-, OH-, CH+, (Co2)-, (Ag2)-, (Co3)-. Photodetachment signals were used to monitor the ion beam lifetime. Populations of rotational levels in OH- were monitored by photodetachment near threshold with a tunable laser. Radiative cooling of the OH- ions was tracked over >5 min when more than 90

11:00-11:30: Project of Electron Cooler for NICA Collider

Igor Meshkov (JINR)

The problems of a development of high energy electron coolers are discussed on the basis of the existing experience. A necessity of electron cooling application to NICA collider are considered and the project parameters of the electron cooler at NICA collider are presented. Electron cooler of the NICA Collider is under design and development of its elements at JINR. It will form an intense ion beam and maintain electron energy range of 0.5 – 2.5 GeV. To achieve the required energy of the electrons all elements of the Cooler are placed in the tanks filled with sulfur hexafluoride (SF6) under pressure of 6 atm. For testing the Cooler elements the test bench ``Recuperator'' is used and upgraded. The results of testing of the prototype of the Cooler elements and the present stage of the technical design of the Cooler are described in this paper.

11:30-12:00: ERL Cooling Ring Concepts for the MEIC

Steve Benson (Jefferson Lab)

The MEIC design at Jefferson Lab will collide electrons in a storage ring with ions in a separate ring. In order to enhance the luminosity, the ions must be cooled in a cooling channel. The required current and charge necessary to cool the ions is on the order of 200 mA and 420 pC at an electron energy as high as 55 MeV. This is too high for a DC accelerator such as a pelletron and so the electron beam must be provided by an Energy Recovery Linac (ERL). This presentation will discuss two options for such an ERL and show some early results of modeling and simulation for these designs. At least at the highest energy, the beam quality seems to be good enough to provide a reasonable cooling rate for the ions.

12:00-12:30: Conceptual Design of the HIAF Electron Cooling System

Lijun Mao (IMP/CAS)

A new accelerator complex HIAF is under design at IMP Lanzhou to provide intense primary and radioactive ion beams for nuclear physics, atomic physics and applied researches. The key parts of HIAF are the booster ring which is used to accumulated heavy ions and the spectrometer ring which can be used as platform for nuclear and atomic physics experiments. A magnetized electron cooling device is supposed to be used in the booster ring for decreasing the transverse emittance of injected beams. Meanwhile, a magnetized electron cooling device together with a ultra-low temperature electron target are also considered to be equipped in the spectrometer ring. In this paper, the conceptual design and main parameters of the electron cooling devices are presented, and the instabilities of cooled high intensity heavy-ion beams are discussed preliminarily.

13:30-14:00: Overview of Development of High Current Electron Sources for ERL Based Bunched Beam Electron Cooling

Matt Poelker (Jefferson Lab)

New initiatives at Jefferson Lab require photoguns operating at 350 kV bias voltage. These initiatives include the construction of a test beamline to study high bunch-charge magnetized beams needed for cooling proton beams at electron-ion colliders. Worldwide, a number of groups have made great progress developing photoguns operating at 350 kV and higher. This contribution describes Jefferson Lab's efforts to build such a gun, but with an inverted-insulator geometry. The inverted-insulator geometry offers advantages over gun designs that employ large cylindrical insulators, but it introduces at least one new challenge, namely, how to reliably apply voltage to the cathode electrode via a high voltage cable without breakdown, which sometimes leads to puncture and catastrophic failure of the insulator. In addition, this contribution describes recent studies devoted to improving our understanding of field emission, and methods to eliminate it. The talk will conclude with a brief discussion of perceived advantages/disadvantages of different high current electron gun options, which could serve as starting-point road map aimed at identifying necessary future R&D.

14:00-14:30: High Current ERL Technology

Dmitry Kayran (BNL)

High current ERL is essential for high energy electron coolers: magnetized, non-magnetized, coherent and other. SRF Linac with well dumped HOMs and high current low energy electron injector are required. At BNL the R&D high-current ERL is under commissioning. The key components of this ERL are: the highly damped 5-cell superconducting RF cavity and the high-current superconducting RF gun. The gun is equipped with multi-alkaline photocathode insertion system. Gun and Linac operating RF frequency is 703.59 MHz. Current laser operates at 10 MHz. The R&D ERL is designed to generate 350 mA of average current. The unique design of merger system allows operating at low injection energy while preserves emittance. The flexible returning loop optics allowed to study different aspects of stability operation. Recently 500 pC per bunch charge and 5mA current in short pulses has been demonstrated. Some aspects of BNL R&D ERL design and beam tests results will be discussed. After ERL commissioning in BLDG 912 the ERL will be relocated to RHIC IP2 to be used for LEReC.

14:30-14:50: Formation of Bunched Electron Beam at the Electron Cooler of CSRm

Xiaodong Yang (IMP/CAS)

The motivation for formation of bunched electron beam at the electron cooler of CSRm is based on the three requirements. Firstly, the high energy electron cooling, especially, the ion beam with TeV energy, the bunched electron beam for cooling would be easier than the DC operating mode. Secondly, the electric field induced by the intensity modulated electron beam will be used for the suppression of instability developed in the high intensity ion beam after accumulation with the help of electron cooling, Thirdly, the electron beam was required to turn on and off in the different period of the atomic physics experiments. Some initial design and consideration were presented in this paper. And also the current situation and condition of CSRm electron cooler were described here. An off-line testbench will be established in the laboratory, and the test and the optimization will be explored in this experimentation. The validity of this system will be verified in the near future. The procedure of the modulation on the voltage of control electrode in the electron gun of the CSRm cooler was discussed. The scheme of off-line measurement was devised according to the progress.

14:50-15:10: Development of an Ultra Fast RF Kicker for an ERL-based Electron Cooler

Amy Sy (Jefferson Lab)

The staged approach to electron cooling proposed for Jefferson Lab's Medium Energy Electron-Ion Collider (MEIC) utilizes bunched beam electron cooling with a single-pass energy recovery linac (ERL) for cooling in the ion collider ring. Possible luminosity upgrades make use of a full circulator ring for multi-pass energy recovery and will require ultra-fast kickers that are beyond current technology. A novel approach to generating the necessary ultra-fast (ns-level) RF kicking pulse involves the summation of specific subharmonics of the cooling electron bunch frequency; the resultant kicking pulse is then naturally constrained to have rise and fall times equal to the electron bunch frequency. The uniformity of such a pulse and its effects on the beam dynamics of the cooling electron bunch will be discussed. Preliminary experimental work will also be presented.

15:30-16:00: Laser Cooling of Relativistic Ion Beams - Recent Results and Future Perspectives

Michael Bussmann (HZDR)

Compared to other cooling techniques laser cooling potentially provides a cooling force that increase with increasing beam energy. Thus, laser cooling will be adopted at future high energy ion storage rings such as SIS 100 at FAIR. In the talk we discuss the fundamentals of laser cooling and the prospects of the technique in the light of recent developments in laser technology and new theoretical investigations on cooling transitions. We present our analysis on the choice of ions for initial test experiments in the light of recent results at ESR and CSRe. The presentation will conclude by analysing the beam dynamics of laser cooled ion beams and from these show how optical diagnostics can complement conventional beam diagnostics.

16:00-16:30: Coulomb Crystallization of Highly Charged Ions

Lisa Schmöger (MPI-K)

Electronic and nuclear wave functions significantly overlap for inner-shell electrons. Their quantum state is strongly influenced by the resulting enhancement of relativistic, QED and nuclear size effects. In highly charged ions (HCIs), the relative reduction of electronic correlations contributions improves the visibility of the underlying physics phenomena. These facts have driven research efforts with HCIs, yet the typically high temperatures (MK) at which they are produced and trapped in the laboratory constitute a hindrance for application of laser spectroscopic methods. To overcome this, we have interfaced an electron beam ion trap source for HCIs with a cryogenic linear Paul trap that can also store laser-cooled Be+ Coulomb crystals. Those are used for sympathetic stopping and cooling of the incoming precooled and decelerated HCI bunches, inducing the formation of stable mixed-species crystals. The strongly suppressed thermal motion (mK scale) of the co-crystallized HCIs offers novel possibilities for investigation of questions regarding the time variation of fundamental constants, parity non-conservation effects, and quantum electrodynamics.

16:30-16:50: Simulation Studies on Intensity Limitations of Laser Cooling at High Energy

Lewin Eidam (GSI)

In the past the principle of Doppler laser cooling was investigated and verified in storage rings at low beam intensities in the low energy regime. Within the FAIR project laser cooling should be applied to intense ion bunches at high energies. Laser cooling results in a further increase of the longitudinal phase space density and in non-Gaussian longitudinal beam profiles. In order to ensure stable operation and optimize the cooling process, the interplay of the laser force and intensity effects has to be studied numerically. At high energies the longitudinal motion in the RF bucket slows down. Depending on the synchrotron frequency the efficiency of laser cooling will be analyzed. For higher beam intensities intra beam scattering and space charge counteract the cooling force. The effects on the cooling process and the impact on cooling equilibriums will be discussed.

16:50-18:00 : Poster Session II

TUPF01 : Cooling for a 100 TeV Proton-Antiproton Collider that Exploits Large Quark-Antiquark to X Cross Sections

Sandra Oliveros (UMiss)

A 10^{34} luminosity 100 TeV proton-antiproton collider is explored. The cross section for many high mass states is 10× higher in p-pbar than p-p. Antiquarks for production can come directly from an antiproton rather than indirectly from gluon splitting. The higher cross sections reduce the synchrotron radiation in superconducting magnets, because lower luminosity can produce the same rare event rates. Events are also more central, allowing a shorter detector with less space between quadrupole triplets and a smaller beta twiss for higher luminosity. To keep up with the antiproton burn rate, a 1.8 GeV phase rotation LINAC is proposed to increase the momentum bite of captured antiprotons at 8.9 GeV/c from 0.02 to 0.20. At Fermilab, antiprotons were stochastically cooled in debuncher and accumulator rings. Because the stochastic cooling time scales as the number of particles, helical stacks of rings to stochastically cool more antiprotons in parallel are explored. Finally antiprotons in the collider ring would be recycled during runs without leaving the collider ring, by joining them to new bunches with synchrotron damping.

TUPF02 : Development of the Electron Cooling Simulation Program for MEIC

He Zhang (Jefferson Lab)

In the medium energy electron ion collider (MEIC) project at Jefferson Lab, the traditional electron cooling technique is used to reduce the ion beam emittance at the booster ring, and to compensate the intrabeam scattering effect and maintain the ion beam emittance during collision at the collider ring. A DC cooler at the booster ring and a bunched cooler at the collider ring are proposed. To fulfill the requirements of the cooling dynamic simulation and the cooler design for MEIC, we are developing a new program, which allows us to simulate the following cooling scenarios: DC cooling to coasting ion beam, DC cooling to bunched ion beam, bunched cooling to bunched ion beam, and bunched cooling to coasting ion beam. The new program has been benchmarked with existing code in aspect of accuracy and efficiency. The new program will be adaptive to the modern multicore hardware. We will present our models and some simulation results.

TUPF03 : Test Experiment of Laser Cooling of Relativistic Li-Like C3+ Ion Beams With a Pulsed UV-Laser System at the CSRE

Weiqiang Wen (IMP/CAS)

A test experiment was performed with 12C3+ ion beams at an energy of 122 MeV/u on the CSRe in September 2014. A pulsed UV laser system from HZDR was employed for this test laser cooling experiment. The closed 2s1/2–2p1/2 optical transition at a wavelength of 155.07 nm of the Li-like carbon ions was Doppler-shifted to be resonant with the UV-laser at the wavelength of 257.5 nm in the experiment. The injected number of C3+ 5×10^8,which was sufficient for testing laser cooling. Stable operation of the CSRe was observed over several days, including rf-bunching and diagnostic systems. The dynamics of the electron-cooled and RF-bunched ion beams were investigated systematically. However, first results did not yet indicate a strong interaction of the laser with the ions. Further data analysis is currently in progress. We will present the experimental results on this workshop, including Schottky spectra of electron-cooled and rf-bunched ion beams, fluorescence signals observed by the UV-sensitive PMT and CPM, and the planning of the upcoming laser cooling experiment at the CSRe.

TUPF04 : The MICE Demonstration of Ionization Cooling

Tanaz Angelina Mohayai (IIT)

Muon beams of low emittance can provide the intense, well known beams for physics of flavour at the Neutrino Factory and multiTev collisions at the Muon Collider. The international Muon Ionization Cooling Experiment (MICE) will demonstrate the technique proposed to reduce the phase-space volume of the muons. In an ionization-cooling channel, the combination of energy loss by muons traversing an absorbing material with reacceleration by RF cavities reduces the transverse emittance of the beam (transverse cooling). The rebaselined MICE project will deliver a demonstration of ionization cooling by Sep 2017: a central Li-H absorber, two superconducting focus-coil modules and two 201 MHz single-cavity RF modules. The phase space of the muons entering and leaving the cooling cell will be measured by two solenoidal spectrometers. All the magnets for the ionization-cooling demonstration are available at RAL and the first single-cavity prototype was tested successfully in the MTA Area at Fermilab. The design of the cooling demonstration experiment, a summary of the performance of each of its components and the cooling performance of the configuration will be presented.

TUPF05 : Dynamic Simulation of Laser Cooling at CSRe

Xiaoni Li (IMP/CAS)

Laser cooling of heavy ion beams at storage ring is one of the most promising techniques to reach high phase-space densities and achieve phase transition, ordered beam even crystalline beam. It has many advantages such as fast-cooling, ultra-strong cooling force and providing the ultra-low temperature (mK) ion beams. Now we introduced the laser cooling at the experimental cooler storage ring(CSRe) at the Institute of Modern Phyics, Chinese Academy of Sciences, and then present the preliminary simulation results of laser cooling at CSRe.

TUPF06 : The Status of MICE Step IV

David Neuffer (Fermilab)

Muon beams of low emittance provide the basis for the intense, well-characterised neutrino beams of the Neutrino Factory and for lepton-antilepton collisions at energies of up to several TeV at the Muon Collider. The international Muon Ionization Cooling Experiment (MICE) will demonstrate ionization cooling — the technique by which it is proposed to reduce the μ-beam phase-space volume. MICE is being constructed in a series of steps. At Step IV, MICE will study the properties of liquid hydrogen and lithium hydride that affect cooling. A solenoidal spectrometer will measure emittance up and downstream of the absorber vessel, where a focusing coil will focus muons. The construction of Step IV at RAL is nearing completion. The status of the project will be described together with a summary of the performance of the principal components. Plans for the commissioning and operation and the Step IV measurement programme will be described.

TUPF07 : Progress of the RF-System Developments for Stochastic Cooling at the FAIR Collector Ring

Stefan Wunderlich (GSI)

An overview of the recent developments regarding the RF signal processing for the stochastic cooling system of the Collector Ring is given. In focus are the developments of generic RF components which can be used at different locations within the signal paths between the pick-up and kicker tanks in the frequency band 1-2 GHz. Two of these components are discussed in detail, a power meter with high dynamic range (+9 dBm to -68 dBm), low phase distortion ($\pm$ 0.75deg(max)) and low attenuation ($\leq$ 0.4dB) and a variable phase shifter with exceptionally flat amplitude ($\pm$ 0.4dB(max)) and linear phase response ($\pm$ 3.5deg(max)). Furthermore, we present the status and the newest enhancements of other components with stringent specifications, such as optical notch filters, pick-up module controllers, variable attenuators, beta-switch combiners and the power amplifiers at the kickers.

TUPF08 : High Efficiency Electron Collector for the High Voltage Electron Cooling System of COSY

Maxim Bryzgunov (BINP SB RAS)

A high efficiency electron collector for the COSY high voltage electron cooling system was developed. The main feature of the collector is usage of special insertion (Wien filter) before the main collector, which deflects secondary electron flux to special secondary collector, preventing them fly to the electrostatic tube. In first tests of the collector in COSY cooler efficiency of recuperation better then 10^{-5} was reached. Before assembling of the cooler in Juelich upgrades of the collector and electron gun were made. After the upgrade efficiency better then 10^{-6} was reached. Design and testing results of the collector are described.

TUPF09 : Decoupling and Matching of Electron Cooling Section in the MEIC Ion Collider Ring

Guohui Wei (Jefferson Lab)

Electron cooling is an important function of MEIC ion collider ring. To realize it, the lattice of the ion ring is inserted of two drift about 31 meters, which are about 100 meters far from the IP (Interaction Point). These two drifts are used to equip two solenoids with 30-meter length to do the cooling job. However, the solenoids can give coupling function and matching problem to the optics of the MEIC ion ring lattice. Both of them will have influence at the IP section and other area, especially for the beam size, twiss parameters, and nonlinear effects. A symmetric and flexible method is used to deal with these two problems. With this method, the electron cooling section is merged into the ion ring lattice elegantly. And this paper will describe it.

TUPF10 : Harmonic Stripline Kicker for MEIC Bunched Beam Cooler

Jiquan Guo (Jefferson Lab)

In the current MEIC design, the ion collider ring needs to be cooled by a bunched electron beam of up to 200 mA 55 MeV, with the possibility to upgrade to 1.5 A. Although it's not impossible to design and build an ERL to provide such a beam, the technical risk and cost associated with such an ERL will be very high. An alternative is to recirculate the electron bunches in a ring for up to 25 turns until the bunch's quality is degraded, reducing the beam current in the ERL by a factor of 25. This scheme requires a pair of fast kickers that kick one in every 25 bunches. In this paper, we will analyze the electrodynamics of a harmonic stripline kicker for this application, and compare it to a harmonic resonator kicker.

TUPF11 : Progress in Experimental Demonstration of Cooling of Ions by a Bunched Electron Beam

Lijun Mao (IMP/CAS)

Electron cooling is essential for achieving high luminosities for hadron colliders by enabling a reduction of emittance of hadron beams in storage rings. For several future projects such as low energy RHIC cooling program (LEReC) at BNL, a low energy electron-ion collider based on HIAF at IMP and a Medium energy Electron-Ion Collider (MEIC) at Jefferson Lab, since the hadron beam energies are in a range from several GeV to 100 GeV, the required electron energy is up to 55 MeV. Such high energy electron beams can only be provided by a RF/SRF linac. As a result, the electron beam is highly bunched. Cooling of ions by a bunched electron beam has never been realized before, thus it becomes a critical R&D to these projects. Recently we proposed a proof-of-concept experiment to demonstrate cooling by a bunched electron beam utilizing an existing DC cooler at IMP. Here we present a progress report of this experiment. We briefly describe the experiment and show the design parameters. We then report hardware installation and results of the bench tests. We also summarize the results of the cooling simulation studies and discuss the required beam measurement capability.

TUPF12 : Single-Pass Simulations of Coherent and Conventional Electron Cooling Schemes

Ilya Pogorelov (Tech-X)

Relativistic electron cooling is a key technology for achieving high luminosity required by the next generation of electron-ion and hadron-hadron colliders. We present a selection of computational techniques developed over the past several years for modeling the cooling physics on the ``microscopic'' timescales, i.e., during a single traversal of the cooling system. We will discuss modeling of the coherent electron cooling (CeC) scheme and its variants, and also the computation of the dynamical friction force responsible for conventional electron cooling. Modeling CeC requires a coupling between delta-f-PIC simulation of the modulator, customized simulations of the FEL amplifier, and electrostatic PIC simulations of the kicker subsections of the CeC cooler. Improved algorithms for computing the dynamical friction in single-pass frictional cooling simulations allow to control noise and correctly account for the statistics of rare but strong small-impact-parameter electron-ion collisions. We will present and briefly discuss the results of our simulations for the parameters of the CeC Proof-of-Principle Experiment at RHIC and the proposed MEIC CCR.

TUPF13 : Microbunching Instability in Recirculation Arcs

Rui Li (Jefferson Lab)

Microbunching instability is one of the most challenging issues in the design of the transport lines for recirculating or energy recovery linac machines. We have developed a linear Vlasov solver to incorporate relevant collective effects, including coherent synchrotron radiation (CSR) and longitudinal space charge (LSC) impedances, for a general linear beamline analysis. With application of this code to two specially designed recirculation arcs and a circulating cooler ring design of MEIC at Jefferson Lab, the resultant microbunching gain functions are presented. Some underlying physics with inclusion of these collective effects are discussed. We expect that the analysis can help illustrate the microbunching gain evolution and its spectral response, and further improve the advanced beamline designs.

8:00-8:30 : Continental Breakfast

8:30-9:00: Recent Progress in the Coherent Electron Cooling Experiment

Vladimir Litvinenko (BNL)

In this talk I will present progress in theoretical, simulation and experimental aspects of Coherent electron Cooling. I will present current status of the accelerator and other system under construction at RHIC for demonstration experiment.

9:00-9:300: Matched Electron Cooling

Slava Derbenev (Jefferson Lab)

Electron cooling of an ion beam is considered in a ring with coupled optics matched with the solenoid of a cooling section. Betatron motion of ions is then represented as a superposition of the two independent circular modes of the two uncorrelated uncoupled canonical emittances, similar to the drift and cyclotron modes of an electron beam in a solenoid. Then cooling of the ion cyclotron mode is not limited by the ion space charge. Cooling of the drift mode is attained by use of dispersion of both beams introduced to the solenoid section. Ion optics organized in this way allows one to drastically diminish the space charge impact on the 4D emittance at beam stacking in a booster and cooling in a collider ring, thus enhancing the cooling rate. Equilibrium due to the IBS is estimated. We also evaluate the gain in luminosity by means of a round to flat beam transformation around the Interaction Point.

9:30-10:00: Optical Stochastic Cooling at IOTA ring

Valeri Lebedev (Fermilab)

The optical stochastic cooling (OSC) represents a promising novel technology capable to achieve fast cooling rates required to support high luminosity of future hadron colliders. The OSC is based on the same principles as the normal microwave stochastic cooling but uses much smaller wave length resulting in a possibility of cooling of very dense bunches. In this paper we consider basic principles of the OSC operation and main limitations on its practical implementation. Conclusions will be illustrated by Fermilab proposal of the OSC test in the IOTA ring.

10:00-10:20: Single-pass-amplifier for Optical Stochastic Cooling Proof-of-Principle Experiment at IOTA

Matthew Andorf (Northern Illinois University)

We report on the latest design for a single-pass, mid-IR Cr:ZnSe optical amplifier to be used for the Optical Stochastic Cooling proof-of-principle experiment in the Integrable Optics Test Accelerator (IOTA) ring located at Fermilab Accelerator Science & Technology (FAST). We present an estimate of the gain and consider effects of thermal lensing. A conceptual design of the amplifier and associated optics is provided.

10:40-11:10: Single-pass Simulation Studies of High Energy Electron Cooling — Review and Future Directions

David Bruhwiler (RadiaSoft LLC)

We review computational work on single-pass dynamics for relativistic hadrons in electron cooling systems relevant to high-luminosity electron-hadron colliders. We identify parameter regimes where binary collisions must be correctly treated and where they can be neglected. The mathematically correct derivation of non-magnetized dynamical friction is presented, showing how the modified Pareto distribution of impact parameters can lead to incorrect interpretation of numerical results. We discuss important aspects of dynamical friction in magnetized electron cooling that require additional study.

11:10-11:40: Emittance Growth From Modulated Focusing and Bunched Beam Electron Cooling

Michael Blaskiewicz (BNL)

The Low Energy electron Cooling (LEReC) project at Brookhaven employs an energy recovery linac to supply electrons in the 1.6 to 5 MeV range. Along with cooling the stored ion beam these bunches create a coherent space charge field which can cause emittance growth. This process is investigated both analytically and via simulation.

11:40-12:10: Space Charge and Csr Microwave Physics in a Circulated Electron Cooler

Rui Li (Jefferson Lab)

Circulator cooler ring (CCR) was proposed as a scheme to alleviate the high demand for the average current of the cooling beam from the electron source. However, transporting the high-brightness cooling beam through CCR for multiple turns, while preserving the phase space quality of the beam, presents significant challenges for the CCR design. In this presentation, we describe our studies on the microbunching instability (uBI) induced by the CSR and longitudinal space charge interactions, and present results of microwave physics for a non-magnetized beam circulating in an early design of CCR of MEIC. It is envisioned that CCR designed for a magnetized beam will have much reduced microbunching effects. A future plan for such study will be discussed.

12:10-12:30: Electron Cooling at GSI and FAIR — Status and Latest Activities

Jon Robach (GSI)

The status, function and operation parameters of the existing and future electron coolers at GSI and FAIR are presented. We report on the progress of the ongoing recommissioning of the former CRYRING storage ring with its electron cooler at GSI. First systematic results on the cooling of a 400 MeV proton beam during the last ESR beamtime are discussed. Motivated by the demands of the experiments on high stability, precise monitoring and even absolute determination of the velocity of the electrons i.e. the velocity of the electron- cooled ion beams, high precision measurements on the electron cooler voltage at the ESR were carried out towards the refurbishment of the main high-voltage supply of the cooler. Similar concepts are underway for the CRYRING cooler high-voltage system.

13:30-17:00 : Free Time or Jefferson Lab Facility Tour

8:00-8:30 : Continental Breakfast

8:30-9:00: Exploring New Techniques for Operation and Diagnostics of Relativistic Electron Coolers

Kurt Aulenbacher (HIM)

The Helmholtzinstitut Mainz (HIM) performs test experiments related to a possible improvement of high energy electron coolers. Results and activities concerning non-invasive beam diagnostics and beam control under large operational currents will be presented. Further, progress of our project to use turbogenerators as a means for potential free power generation in high energy electron coolers is presented.

9:00-9:30: The SNS Laser Stripping Injection Experiment and its Implications on Beam Accumulation

Sarah Cousineau (ORNL)

The laser assisted H- charge exchange concept is under development at the Spallation Neutron Source (SNS) as on option for replacing traditional carbon-based foil technology in future accelerators. A laser based stripping system has the potential to alleviate limiting issues with foil technology, paving the way for accumulation of much higher density proton beams. This paper discusses the advantages and limitations of a laser-based stripping system compared with traditional foil-based charge exchange systems for various beam accumulation scenarios, scaling from SNS experience with high power beam injection and calculations of laser stripping parameters. In addition, preparations for an experimental demonstration of laser assisted stripping for microsecond long 1 GeV, H- beams are described.

9:30-10:00: Round-to-Flat Beam Transformation and Applications

Yin-E Sun (ANL)

When the dynamics within an electron bunch is dominated by its angular momentum rather than other effects, the beam is said to be angular-momentum-dominated 'magnetized'. Such a beam can be directly applied to the field of electron-cooling of heavy ions; or it can be manipulated into a flat electron beam with a large transverse emittance ratio. A flat beam is of interest for high-energy electron-positron colliders or accelerator-based light sources where the radiation-generation device has a flat interaction surface. In this talk, the experimental results of round-to-flat beam transformation is presented and possible applications explored.

10:00-10:20: Rf Technologies for Ionization Cooling Channels

Ben Freemire (IIT)

Ionization cooling is the preferred method of cooling a muon beam for the purposes of a bright muon source. This process works by sending a muon beam through an absorbing material and replacing the lost longitudinal momentum with radio frequency (RF) cavities. To maximize the effect of cooling, a small optical beta function is required at the locations of the absorbers. Strong focusing is therefore required, and as a result normal conducting RF cavities must operate in external magnetic fields on the order of 10 Tesla. Vacuum and high pressure gas filled RF test cells have been studied at the MuCool Test Area at Fermilab. Methods for mitigating breakdown in both test cells, as well as the effect of plasma loading in the gas filled test cell have been investigated. The results of these tests, as well as the current status of the two leading muon cooling channel designs, will be presented.

10:40-11:10: The CERN Antimatter Facility

Tommy Eriksson (CERN)

After some 30 years of supplying antiprotons for the various physics programmes at CERN, the antimatter facility with its Antiproton Decelerator (AD) is now undergoing a major upgrade program. A report of the operational status of the facility in its current configuration is given. In view of the decades ahead of us, we will also discuss ongoing consolidation activities as well as ongoing and planned upgrades including the design and construction of an additional decelerator ring, ELENA (Extra Low ENergy Antiprotons) with the aim of supplying cooled 100keV antiproton beams to the experimental areas via new low-energy beam lines employing electrostatic deflectors and focussing elements.

11:10-11:40: Nica Project, Report on the Present Status and Related Cooling Issues

Grigoriy Trubnikov (JINR)

Nuclotron-based Ion Collider fAcility (NICA) is the new experimental heavy-ion complex being constructed at Joint Institute for Nuclear Research, Dubna. Main purpose of the project is to provide experiment on colliding heavy ion beams (Au) for study of manifestation of hot and dense strongly interacting baryonic matter. The construction of the accelerator complex is actively performed: new 3.2 MeV/u heavy-ion linear accelerator (HILac) is now under commissioning, serial production of Booster synchrotron elements is going in schedule. Systems for collider had been prototyped and start of serial production is in 2015. Beam cooling systems are suggested for application at NICA. The Booster equipped with 35 keV electron cooling system. Two beam cooling systems: stochastic and electron, will be used in the collider. Parameters of cooling systems, proposed scenario of collider operation, design intended to achieve required average luminosity of the order of 10^{27} $cm^{-2}s^{-1}$, start-up version of the complex for 2019 are presented.

11:40-12:10: High Intensity Heavy Ion Accelerator Facility (HIAF) in China

Jiancheng Yang (IMP/CAS)

HIAF (High Intensity heavy ion Accelerator Facility) is a proposed new accelerator facility in China. The HIAF facility will be built on the experience and technological developments already achieved at the existing HIRFL facility and also be incorporated new technological concepts. The facility is being designed to provide intense beams of primary and radioactive ions for a wide range of research fields. High energetic highly bunched heavy ion beams are used to interact with dense plasma to probe the physics of nuclear fusion. Radioactive ion beams are used to investigate the structure of exotic nuclei, to learn more about nuclear reactions of astrophysics and to measure the mass of nuclei with high precision. Highly charged ions are used for atomic physics and a series of applied science. The unique features of the first phase of HIAF are high current pulsed beams from the iLinac and high intensity heavy ion beams with ultra-short bunch from the BRing. The cooled rare isotope beams also will be prepared through projectile-fragmentation (PF) method. The baseline design of HIAF will be chosen to optimize science goals, technology development and project cost. The final design of the first phase will maintain a well defined path for future upgrade. A electron accelerator complex will be developed for the electron-ion collision (EIC) in the second phase. The beam dynamics and technical challenges will be presented, as well as the present status of HIAF project.

12:10-12:30: Status and Upgrade of HIRFL Accelerator Complex at IMP

Youjin Yuan (IMP/CAS)

The Heavy Ion Research Facility at Lanzhou (HIRFL) is the only one large scale heavy ion accelerator complex that uses cyclotron(SFC and SSC) as injector, synchrotron(CSRm) for accumulation and post acceleration, storage ring(CSRe) for in ring experiments in China. To reach the increasing requirements from nuclear physics, atomic physics, interdisciplinary science and their applications, many upgrading plans were launched or scheduled. The present status and recent upgrading plans of HIRFL will be introduced in this paper. The operation of the electron coolers and related cooling experimental results are presented. For the upgrading plans, the development of new Linac injector for HIRFL and the new high voltage system of 300keV electron cooler will be discussed in details.

13:30-14:00: muCool: Towards a Much Improved Phase Space Slow Positive Muon Beam

Andreas Knecht (PSI)

Over the past decades meson production facilities have been providing powerful surface muon beams to experiments with intensities of up to several 10^8 μ^+/s. Due to the production process in dedicated targets and the limited time, the phase space of these beams is generally poor. We are developing a tertiary beamline to decrease the phase space of a mu+ beam by a factor of 10^{10} with an efficiency of 10^{-3}. The idea is to stop the MeV muon beam in helium gas at cryogenic temperatures and compress the muon swarm by means of a gas density gradient and electric and magnetic fields in longitudinal and transversal dimensions. This talk will give an outline of the general principles behind the compression mechanism and give an update on the current experimental status.

14:00-14:30: Progress of Front End and HFOFO Snake

David Neuffer (Fermilab)

Scenarios for capture, bunching, phase-energy rotation and initial cooling of muonss produced from a proton source target have been developed for neutrino factory and Muon Collider designs. The baseline scenarios requires a drift section from the target, a bunching section and a phase-energy rotation section leading into the cooling channel. The cooling channel would be a 'HFOFO snake', which cools in 6-D phase space, preparing the beam for acceleration for high-energy applications or deceleration for low-energy sources. Optimization and variations are discussed.

14:30-15:00: Rectilinear Channel for Muon Cooling Towards Micron Scale Emittances

Diktys Stratakis (BNL)

Generation of bright muon sources requires a reduction of the six-dimensional emittance of the captured muon beam by several orders of magnitude. In this study, we present a new cooling scheme that should meet this requirement. First, we present the conceptual design of our proposed scheme wherein we detail its basic features. Then, we present the first end-to-end simulation of 6D cooling for a Muon Collider and show a notable reduction of the 6D emittance by five orders of magnitude. Finally, we examine the influence of space-charge fields on the cooling process and present a space-charge compensation solution by means of increasing the rf gradient. We establish a quantitative relationship between the required compensation gradient and bunch charge.

15:20-15:50 : Award Session

15:50-16:20: Crystalline Beam Studies with Andy Sessler

Jie Wei (FRIB)

For nearly two decades from 1992 to 2010, Andy Sessler worked with us as a hobby on the topic of crystallization of charged ion beams and cooling methods. In this paper, we review the studies jointly performed with Andy highlighting major findings and challenges, and discuss current status and possible future topics and directions.

16:20-16:50: Cooling and Phase Space Manipulation of Nonneutral Plasmas for Antihydrogen Synthesis

Jonathan Wurtele (LBNL)

The ALPHA collaboration in CERN synthesizes antihydrogen by combining antiprotons with positrons in nested Penning-Malmberg traps. Roughly one or two antihydrogen are synthesized from the 10^7 antiprotons that are provided by each cycle of the CERN Antiproton Deccelerator. Cooling is central to our success. Cooling methods used by ALPHA include collisional cooling of antiprotons on cold pre-trapped electrons, electrons and positrons radiative cooling by cyclotron emission, and evaporative cooling. The neutral trap depth for antihydrogen confinement is 0.54K, which many orders of magnitude smaller than the initial energy, 5MeV, of the antiprotons provided by CERN. The potential energy associated with self-fields of the charged particles is a factor of $10^2 - 10^4$ greater than the neutral trap depth. Moreover, there is heating associated with various phase space manipulations, include compression and mixing. Andy Sessler was, up until his last years, a fairly regular attendee of our group meetings and an ALPHA enthusiast. The story of cooling on ALPHA will be interspersed with stories about Andy's thoughts on cooling, physics, and life in general.

16:50-17:20 : Free Speeches by Andy's Friends

18:00-20:00 : Networking Banquet Reception

8:00-8:30 : Registration and Continental Breakfast

8:30-8:50: Stochastic Cooling Experiments at Nuclotron and Application to NICA Collider

Nikolay Shurkhno (JINR)

Stochastic cooling is obligatory for the NICA accelerator facility that is presently under development at JINR, Russia. Cooling will work with the high-intensity bunched beams in the 3-4.5 GeV energy range; all three dimensions will be treated simultaneously. The preparatory experimental work on stochastic cooling is carried out at accelerator Nuclotron (JINR) since 2010. During this work hardware solutions and automation techniques for system adjustment have been worked out and tested. Based on the gained experience the overall design of the NICA stochastic cooling system was also developed. The report describes the results of cooling experiments at Nuclotron, the developed adjustment automation techniques and presents the design of the NICA stochastic cooling system.

8:50-9:10: Fokker-Planck Approach to the Description of Transverse Stochastic Cooling

Fritz Nolden (GSI)

A Fokker-Planck model of transverse stochastic cooling (without feedback through the beam) is presented, which relies on moderately simplified assumptions about the underlying cooling system. The equilibrium emittance distribution turns out to be always exponential. Furthermore, if the initial distribution is already exponential, then the solution of the fully time-dependent Fokker-Planck equation remains exponential. The average emittance decays with a rate towards equilibrium, which is completely consistent with the classical van der Meer rate, including undesired mixing, desired mixing and thermal noise.

9:10-9:30: Design of the Palmer Pickup for Stochastic Pre-Cooling of Hot Rare Isotopes at the CR

Duncan Barker (GSI)

We report on the design of a Faltin type pickup for the stochastic pre-cooling of rare isotope beams at 740 MeV/u, using a bandwidth of 1-2 GHz, for the Collector Ring (CR) at FAIR. The pickup impedance of Faltin rails increases as the length increases, but the phase of the output signal becomes increasingly nonlinear. To compensate for this effect it is planned to split the available tank length between two separate but identical rails whose signals will be combined outside the tank. The design of the Faltin type pickups consisted of simulations using HFSS and physical measurements of prototypes. The prototypes were measured as a pickup by simulating a beam using a waveguide. Both methods of simulation, measurement and design are compared, discussed and presented.

9:30-9:50: Anti-Particle Accumulation for Low Energy Exotic Beams

Hiroyuki Higaki (Hiroshima University)

On behalf of ASACUSA-MUSASHI collaboration, the recent result for the production of low energy antihydrogen beams is presented. In Antiproton Decelerator (AD) at CERN, low energy antiproton beams of 5.6 MeV have been delivered for physics experiments since 1999. With the help of RF group at CERN, Atomic Spectroscopy And Collisions Using Slow Antiprotons (ASACUSA) collaboration installed the unique RFQ decelerator (RFQD), which can provide 100 keV pulsed antiproton beams for its various experimental programs. Furthermore, the Mono-energetic Ultra Slow Antiproton Source for High-precision Investigations (MUSASHI) used a Penning-Malmberg trap to produce antiproton beams with the energy of 100 to 1000 eV. In 2010, the synthesis of low energy anti-hydrogen atoms in the Cusp trap with the use of 150eV antiproton beams from MUSASHI trap was reported. The purpose of producing low energy anti-hydrogen atoms in a cusped magnetic field is to extract a polarized anti-hydrogen beam to a field free region, so that the hyperfine structure of anti-hydrogen atoms can be measured with a necessary precision.

9:50-10:10: LEPTA — the Facility for Fundamental and Applied Research

Andriy Kobets (JINR)

The project of the Low Energy Positron Toroidal Accumulator (LEPTA) is under development at JINR. The LEPTA facility is a small positron storage ring equipped with the electron cooling system. The project positron energy is of 2–10 keV. The main goal of the facility is to generate an intense flux of positronium atoms, the bound state of electron and positron. Storage ring of LEPTA facility was commissioned in September 2004 and is under development up to now. The positron injector has been constructed in 2005–2010, and beam transfer channel in 2011. By the end of August 2011 the experiments on injection into the ring of electrons and positrons stored in the trap were carried out. In 2012–2015, the LEPTA trap optimization and new experiments on accumulation of electrons and positrons in the trap has been performed. Furthermore new cooler for positrons source has been designed and manufactured, its assembling is in progress. The recent results are presented here.

10:30-11:00: Commissioning of the Rare-RI Ring at RIKEN RI Beam Factory

Yoshitaka Yamaguchi (RIKEN)

The Rare-RI Ring (R3) is an isochronous storage ring to measure masses of short-lived rare nuclei by using a TOF method. The expected precision of the measured mass will be of the order of ppm. A commissioning run using a ^{78}Kr beam was performed in June 2015 and basic performances of R3 were verified. We succeeded in injecting a particle, which was randomly produced from a DC beam from cyclotrons, into the R3 individually with a fast kicker system, and in extracting the particle from the R3 1 ms after the injection. We measured TOF of the 78Kr particles between the entrance and the exit of the R3 to check the isochronism. Through the first-order adjustment with trim-coils imbedded on the dipole magnets of the R3, the isochronism on the 10-ppm order was achieved for the momentum spread of $\pm$0.2%. Higher-order adjustment employed in future will lead us to the isochronism on the order of ppm. In addition, we confirmed that a resonance-type Schottky pick-up successfully acquired the revolution frequency information of one particle in a storage mode. In this conference, the technical aspects of the R3 and prospects from the results of the beam commissioning will be discussed.

11:00-11:40: Science Prospects of a Future Electron-Ion Collider

Abhay Deshpande (Stony Brook University)

11:40-12:00 : Closing Remarks and Announcement of host for COOL'17 Workshop