

Workshop on Beam Cooling and Related Topics

COOL'09

August 31 ~ September 4, 2009

IMP, Lanzhou, P.R.China,



Sponsored by:

**Institute of Modern Physics, CAS
Chinese Academy of Sciences**

COOL'09

August, 31 ~ September, 4, 2009
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Workshop on beam cooling and related topics

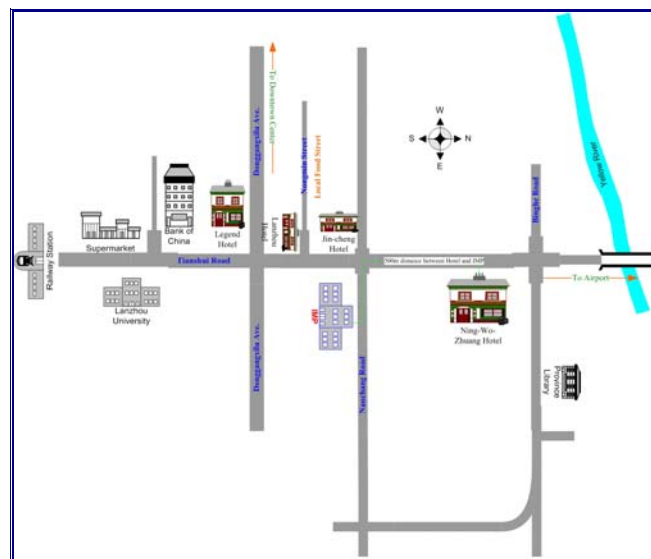
The workshop on beam cooling and related topics, COOL'09 is hosted by Institute of Modern Physics, Chinese Academy of Sciences. It succeeds to previous beam cooling conferences the most recent of which was hosted by GSI (COOL'07)

The workshop on beam cooling and related topics, COOL'09, will highlight the state of the art in the physics and engineering of beam cooling systems and related techniques, including electron, stochastic, laser and ionization cooling. The program includes applications of beam cooling to traps, heavy ion and antiproton beams. Presentations of new developments and techniques as well as of the status of existing and future facilities are invited.

Workshop Venue

The workshop will be held at IMP in Lanzhou:
Institute of Modern Physics, Chinese Academy of Sciences
No.509 Nanchang Road,
730000, Lanzhou
P.R.China

Phone: (+86) 931-4969221
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Registration and Information Desk

Registration fee applies to all participants, including invited speakers and chair persons. Payment should be made by bank transfer in advance (reduced fee of 450 € compared to 500 € at the workshop). Credit card (VISA or MASRTE) payment or cash will be organized on Sunday at the conference desk.

The registration fee includes all materials of the workshop including the proceedings and the book of abstracts, the workshop coffee breaks and lunch buffet through Monday to Friday, the Get-together reception (Sunday) and conference banquet (Wednesday), the technical tour of the IMP facilities, the conference excursion, the transport between the hotel and Lanzhou airport (70km).

Registration will take place at the conference hall in the Institute of Modern Physics during the following opening hours of the registration and information desk:

Sunday, 30 August 2009	14:30-20:00
Monday, 31 August 2009	08:30-17:30
Tuesday, 1 September 2009	08:30-17:30
Wednesday, 2 September 2009	Excursion
Thursday, 3 September 2009	08:30-17:30
Friday, 4 September 2009	08:30-17:30

Meals

The price of the hotel includes breakfast. For workshop participants the lunch buffet offered from Monday to Thursday is included in the registration fee. The fee also includes the morning and afternoon coffee breaks. On Friday, lunch at the hotel can be arranged and must be paid extra. Meals at dinner time, except the conference dinner on Wednesday, are not included in the workshop fee.

Companions

The registration fee for each accompany person is 250 €, which includes get-together reception, conference banquet, lunch through Monday to Thursday, the conference excursion, transport between Lanzhou airport and the hotel, and a guided tour to nearby attractions.

Workshop Program

The workshop starts Monday morning, 31 August 2009, at 8:30, and is organized as follows. There are two morning and two afternoon sessions on Monday and Tuesday. There are two morning sessions on Thursday and Friday. The afternoon session on Thursday is a poster session, followed by general talks (Teatime talk) given by Hushan Xu from IMP on Physics with stored and cooled ion beam at HIRFL-CSR and E.G.Bessonov from LPI on The evolution of the phase space density of particle beams in external fields. The workshop ends on Friday, 4 September 2009, at about 12:30.

Oral Presentation

A personal computer operating under Windows Vista (English version) will be available for the electronic presentations. The following software will be installed on the computer:

PowerPoint 2003
Word 2003
Acrobat Reader 9.0

The time for oral contributions (invited and contributed) is 25+5 minutes. In order to provide enough time for discussion the time limit for the talk should not be exceeded.

Posters

Poster boards with a size of 2m height and 1m width will be provided. The posters should be mounted after the Thursday morning session and should be manned Thursday afternoon between 14:00 and 16:00. Mounting material will be provided.

Workshop Proceedings

The conference proceeding will be published with JACoW. The proceedings will be available on the COOL'09 homepage.

The deadline for submission of papers is August 29, 2009. The page limit is 5 pages for invited speakers and 4 pages for others. Instructions for the preparation of proceedings can be found on the JACoW website, where templates for WORD and LaTeX can be downloaded.

The electronic files of contributions to the proceeding will be processed during the workshop. The editing will be performed in cooperation with the authors and should be finished by the end of the workshop. No editing after the conferences is planned. Authors should submit all source files needed to prepare the paper and a postscript version. They should bring a hard copy of the paper to the workshop. We kindly ask all authors to respect the deadline for paper submission before the conference, which is crucial for publication of the proceedings.

Internet Cafe

An Internet cafe is located next to the registration room beside the auditorium. A few personal computers with internet access as well as wireless connections will be available free of charge in this area. Wireless access in the rooms can be provided by the hotel.

Insurance

Attendants of the workshop are expected to have a proper health and personal liability insurance. No responsibility can be taken by the organizers.

Travel

It is 70 km away from Lanzhou Zhongchuan Airport to Ning-Wo-Zhuang Hotel. Participants are kindly requested to inform the local organizing committee your arrival date, flight number, and landing time; we will pick up you at the airport and drive you to the hotel. Please directly send your arrival information by email to cool09@impcas.ac.cn. Additionally, there is also hourly airport shuttle bus that drives you to the downtown of Lanzhou (the last stop of the

shuttle bus is near to Lanzhou University, which is only about 700 meters away from Ning-Wo-Zhuang Hotel). If you come to Lanzhou by train, you can take the No. 10 bus to reach Ning-Wo-Zhuang Hotel or IMP (the Train Station is about 2km away from IMP).

Program Committee

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Hongwei Zhao(Chair)

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MON-M1 — Monday Morning Session 1

Status of Antiproton Accumulation and Cooling at Fermilab's Recycler

Lionel Prost - Fermilab

The Recycler ring is an 8 GeV permanent magnet storage ring where antiprotons are accumulated and prepared for Fermilab's Tevatron Collider program. With the goal of maximizing the integrated luminosity delivered to the experiments, storing, cooling and extracting antiprotons with high efficiency has been pursued. In this paper, we discuss recent changes made to the Recycler Electron cooler (energy stability and regulation, electron beam optics), RF manipulations and procedures, in order to optimize cooling while preserving the antiprotons lifetime and avoiding instabilities.

Antiproton Decelerator Status Report

Lajos Bojtar - CERN

The Antiproton Decelerator (AD) has been delivering 5.3 MeV antiprotons to the experiments for 10 years now. Beam cooling is essential for the AD operation. We review the AD machine and in particular the cooling performance. We give an overview of the present and future experiments and also the possible further deceleration of the beam from 5.3 MeV to 100 KeV kinetic energy.

MON-M2 — Monday Morning Session 2

Electron cooling for Low-Energy RHIC program

Alexei V. Fedotov - BNL

Electron cooling was proposed to increase luminosity of RHIC collider for heavy ion beam energies below 10 GeV/nucleon. Providing collisions at such energies, which in RHIC case is termed "low-energy" operation, will help to answer one of the key questions in the field of QCD about existence and location of critical point on the QCD phase diagram. Electron cooling system needed should deliver electron beam of required good quality in a range of electron beam energies of 0.9-5 MeV. Several approaches which can provide such cooling were considered. The baseline approach was chosen and design work started. Here we describe the main features of the cooling system and its expected performance.

Application of cooling methods to NICA project

Alexander V. Smirnov - JINR

Nuclotron-based Ion Collider fAcility (NICA) is the new accelerator complex being constructed on the JINR site. General goal of the project is the experimental study of hot and dense strongly interacting QCD matter and search for possible manifestation of signs of the mixed phase and critical endpoint in heavy ion collisions. A few cooling systems are considered for the NICA project: electron one for the Booster-synchrotron and for Collider rings; both electron and stochastic ones. The main goal of the Booster electron cooler is a

decrease of the longitudinal emittance from the injection value to the necessary value for acceleration in Nuclotron. The Booster electron cooling system can be also used at injection for the stacking procedure. The designed electron and stochastic cooling systems for Collider rings have to prevent the emittance growth due to the intrabeam scattering and to keep the average luminosity on the constant value. Both cooling systems of the Collider rings can be used for the injection scheme with barrier bucket RF system. The magnetic field in electron cooling and beam transportation sections of the coolers will be formed with superconducting solenoids.

Cooling experiments at COSY in preparation for the HESR

Dieter Prasuhn - FZJ

The cooler synchrotron COSY can be both from hadron physics point of view as well as from the accelerator side looked at as the smaller predecessor of the proposed High Energy Storage Ring (HESR) at the Facility for Antiproton- and Ion Research (FAIR) in Darmstadt. Both electron and stochastic cooling are foreseen in the HESR to fulfill the demanding requirements on beam quality from the PANDA experiment. Intense beam dynamic studies and prototype testing for HESR have been and will in future be performed at COSY to study beam equilibrium properties under the influence of thick internal targets, stochastic and electron cooling in a storage ring. Results of simulations and measurements will be presented.

MON-A1 — Monday Afternoon Session 1

Laser Cooling at ESR, CSR and FAIR

Michael Hans Bussmann - FZD

Laser cooling of ion beams is a promising technique to achieve ultracold ion beams of unprecedented brilliance in storage rings. Recent experiments at the ESR/GSI have shown that laser cooling at relativistic beam energies is feasible, opening the route towards laser cooling at future storage rings such as SIS300/FAIR. In this talk we present recent results on laser cooling of C³⁺ ion beams at the ESR. The results presented show that with laser-cooling space-charge dominated ion beams are observed with at least one order of magnitude smaller momentum spread than attained with electron cooling. This allows to reach the regime of strong coupling, which is a prerequisite for beam crystallization. Based on these results we present new experiments planned at ESR and CSR which will take full advantage of all-optical beam diagnostics that will allow to overcome the limited resolution of standard ion beam diagnostics. In combination with all-optical cooling schemes which do not rely on initial electron cooling of the ion beam, laser cooling is one of the most promising candidates for cooling ion beams at ultra-relativistic energies accessible at the future FAIR facility.

Operation and Upgrade of Stacktail Cooling System

Valeri Lebedev - Fermilab

Upgrades and improvements of stacktail system have been important part of Tevatron Run II. The paper describes measurements and simulations allowing us to reach the peak stacking

rate of 30×10^{10} 1/s as well as the principles of design and operation of the system. The core heating by stacktail is a serious phenomenon limiting the stacking rate. The paper also discusses heating mechanisms and ways to mitigate them.

Stochastic Accumulation of antiprotons for RESR

Fritz Nolden - GSI

We present a design for accumulation in the RESR in the frame of the FAIR project at GSI. A longitudinal accumulation scheme has been worked out using simulation codes which include the effect of feedback through the beam.

MON-A2 — Monday Afternoon Session 2

Twenty-five Years of Stochastic Cooling Experience at Fermilab

Ralph James Pasquinelli - Fermilab

In the early 1980s, it was decided that Fermilab would build a proton antiproton collider to search for the top quark following the successes at CERN with the discovery of the W and Z bosons. The effort was designated the Tevatron 1 project. The Tevatron began fixed target operations in 1983 at 800 GeV. Design of an antiproton source began in earnest in 1981 and a construction start in 1983. The first antiprotons were delivered to the Tevatron in October of 1985 and collisions were observed in the CDF detector. The Antiproton Source consists of two accelerators, the Debuncher and Accumulator. The Debuncher ring performs bunch rotation and pre-cooling, the Accumulator ring utilizes stochastic cooling for antiproton collections. This paper will present the chronology of the cooling systems development from those early days to the current record setting performance.

Numerical Study of Stochastic Stacking of the 3 GeV Anti-Proton Beam in the RESR of the FAIR Project

Takeshi Katayama - GSI

In the FAIR project at GSI the cooled anti-proton beam from the Collector Ring (CR) is accumulated in the accumulator ring, named RESR. The accumulation scheme in the RESR is stochastic stacking as successfully performed at CERN and FNAL. In the present design, two tail- and a core cooling systems are used to obtain a high dense beam of 1×10^{11} anti-protons after 1000 shots with a cycle time of 10 seconds between consecutive injections. A detailed numerical study with the use of the Fokker Planck equation has been performed to optimize the parameters. The procedure and numerical results will be presented.

Optical stochastic cooling insertion designs in a laser-electron storage ring

Xiaozhe Shen - TUB

The feasibility study of the optical stochastic cooling (OSC) applied in a compact storage is presented in this paper. Based on the two different running modes of the compact storage ring, we design two different OSC schemes which include the main lattice design, OSC components parameters optimization, and evaluation of the errors tolerance. Simulations

results of the beam profile evolution together with the emittance changes during the cooling process are likewise presented, in which the effects of Intrabeam Scattering (IBS), Compton Scattering (CS), and Synchrotron Radiation (SR) are taken into account.

TUE-M1 — Tuesday Morning Session 1

Muon Cooling R&D for the Muon Collider - a 5 year plan for the US

Alan David Bross - Fermilab

The Neutrino Factory and Muon Collider Collaboration and the Fermilab Muon Collider Task Force have recently submitted a proposal to the US Department of Energy Office of High Energy Physics to deliver a Design Feasibility Study for a Muon Collider after a 5 year R&D program. This talk will present a brief physics motivation and description of a Muon Collider facility, give an overview of the proposal, and then discuss in some detail the technical components of the proposal with respect to the muon ionization cooling R&D required in order to prove the feasibility of an Energy-Frontier, high luminosity Muon Collider.

Enhanced optical cooling of muon beams

Evgeniy Grigorievich Bessonov - LPI

The possibility of the Enhanced Optical Cooling of muon beam in a storage ring is investigated. The rate of the energy loss by muons in this scheme of cooling remains constant and equal to the maximal one independently on the deviation of their energy from the energy of the reference muon. Fast non-exponential cooling takes place: the lesser amplitudes of oscillations - the faster cooling is. The degree of cooling is limited by the resolution of the muon beam in the pickup undulator and equilibrium beam dimensions *.

Frictional Cooling Demonstration at MPI

Yu Bao - MPI fuer Physics

Frictional Cooling holds promise for delivering beams with a very narrow energy spread. A demonstration experiment based on this scheme has been undertaken at Max-Planck-Institute for Physics (MPI-Munich). The data will be taken soon. In this paper, the experimental setup is described followed by the Monte-Carlo simulation results based on Geant4. In addition, the use of frictional cooling aiming at improving the efficiency for producing a low energy muon beam is also investigated. Simulation results give an energy peak at 3 keV with a spread of about 300~400 eV. The simulations indicate that the efficiency compared to existing schemes is increased by 2 to 3 orders of magnitude.

Six-Dimensional Cooling Simulations For The Muon Collider

Pavel Snopok - UCR

The two cooling channels based on the RFOFO ring concept are considered and simulated. One of them is the RFOFO helix, also known as the Guggenheim. The helical shape of the channel resolves the injection and extraction issues as well as the absorber overheating issue. The issue of the RF breakdown in the magnetic field is addressed in the so-called open-cavity

cooling channel lattice with magnetic coils in the irises of the RF cavities. The details of the tracking studies of both channels are presented and compared to the performance of the original RFOFO cooling ring design.

TUE-M2 — Tuesday Morning Session 2

Compensation of Mean Energy Loss due to an Internal Target by Application of a Barrier Bucket and Stochastic Momentum Cooling at COSY

Takeshi Katayama - GSI

The High Energy Storage Ring (HESR) of the future International Facility for Antiproton and Ion Research (FAIR) at the GSI in Darmstadt will be built as an anti-proton cooler ring in the momentum range from 1.5 to 15 GeV/c. An important and challenging feature of the new facility is the combination of phase space cooled beams with internal targets. Detailed numerical studies of longitudinal filter and time-of-flight cooling including an internal target and intrabeam scattering have been carried out to demonstrate the stochastic cooling capability. It has been found that the strong mean energy loss due to the internal target can not be compensated by cooling alone. Experimental results at COSY to compensate the large mean energy loss induced by an internal Pellet target similar to that being used by the PANDA experiment at the HESR with a barrier bucket cavity (BB) will be presented. The results are compared with numerical simulations. Experimental tests of stochastic filter cooling with internal target and BB operation as well as expected cooling properties for the HESR are discussed. First results of time-of-flight cooling with an internal target at COSY will be presented.

Particle accumulation with using of barrier bucket RF system

Alexander V. Smirnov - JINR

Using of the barrier bucket system for the accumulation process was proposed for a few accelerator projects. This rather new idea can bring new advantages to the accelerator physics. The principle possibility of this accumulation method with moving and stationary barrier bucket in the presence of the electron cooling was successfully demonstrated on the ESR storage ring last year. The article presents results of the numerical simulation and comparison with ESR experiments. The aim of this work is an investigation of the accumulation process and optimization of the parameters of the cooling and barrier bucket systems. The numerical simulation of the accumulation process with stationary barrier bucket system for the NESR storage ring was done with different program codes in the presence of the electron and stochastic cooling systems. The discussion and comparison of these simulations are presented.

TUE-A1 — Tuesday Afternoon Session 1

Status of the International Muon Ionization Cooling Experiment (MICE)

Derun Li - LBNL

Muon ionization cooling provides the only practical solution to prepare high brilliance beams

necessary for a neutrino factory or muon colliders. The muon ionization cooling experiment (MICE)* is under development at the Rutherford Appleton Laboratory (UK). It comprises a dedicated beam line to generate a range of input emittance and momentum, with time-of-flight and Cherenkov detectors to ensure a pure muon beam. A first measurement of emittance is performed in the upstream magnetic spectrometer with a scintillating fiber tracker. A cooling cell will then follow, alternating energy loss in liquid hydrogen and RF acceleration. A second spectrometer identical to the first one and a particle identification system provide a measurement of the outgoing emittance. In September 2009 it is expected that the beam and some detectors will be in the final commissioning phase and the time of the first measurement of input beam emittance only months away. The plan of steps of measurements of emittance and cooling, that will follow in the rest of 2009 and later, will be reported.

Possible Collective Effect in Ionization Cooling

King Yuen Ng - Fermilab

In the process of ionization cooling, as a charged particle passes through absorber, it induces wake field by polarizing the absorber. As a result, the momentum loss of each particle along its direction of motion may be coherently increased and cooling effect may be enhanced. To understand this coherent effect more accurately and test the enhancement feasibility, preliminary studies have been carried out and results are obtained.

Progress of Helical Cooling Channel Design for Muon Colliders

Katsuya Yonehara - Fermilab

The most challenging part in muon collider is to make six dimensional muon phase space cooling within their short lifetime. A helical cooling channel (HCC) is proposed to obtain the exceptional cooling performance in a short channel length. Various studies for HCC have been progressed in experimental and simulative ways. We will discuss current status of the project in this presentation.

TUE-A2 — Tuesday Afternoon Session 2

Status and challenges in beam crystallization

Jie Wei - BNL

During the past several decades, beam crystallization has been studied both theoretically and experimentally. Theoretical investigations have been numerical, mainly using computer modeling based on the method of molecular dynamics (MD), and analytical, based on phonon theory [1]. Experimental investigations involve both ion storage rings and ion traps using both electron and laser beam cooling. Topics of interests include crystal stability in various accelerator lattices and under different beam conditions, colliding crystalline beams [2], crystalline beam formation in shear-free ring lattices with both magnets and electrodes [3], experimental simulation of alternating-gradient conditions with an ion trap, tapered cooling and coupled cooling, and beam dynamics at different temperature regime as the beam is

cooled from high to low temperature. In this paper, we first review theoretical approaches and major conclusions pertaining to beam crystallization. Then, we analyze conditions and methods of the various major experiments. Finally, we discuss, both theoretically and experimentally, some improvements, open questions, and challenges in beam crystallization.

Proof of Principle for Muon Phase Rotation in 6-Sector FFAG Ring

Takahisa Itahashi - Osaka University

A closed orbit study and betatron tune measurement has been achieved in the 6-sector FFAG ring. The alpha particle beam of the same momentum as that of mono-energetic muon is injected and detected with a scintillating bar and a semiconductor detector. Two simulation results for closed orbit are compared with the measurement and discussed with taking into account the magnetic field mapping data. The modulated energy spectra in energy measurement are observed by applying the RF voltage to the cavity since the energy of alpha particles are accelerated and decelerated with an individual phase of alpha particle appeared in the cavity gap. External injection of alpha particle is tried with static inflector electrodes.

The GANIL/Spiral II/DESIR High Intensity Radiofrequency Cooler

Gilles Ban - CNRS/IN2P3/LPC CAEN

The Spiral2 facility which will be implanted at GANIL, Caen, France, is the second generation of radioactive beam facilities. Spirall II will deliver intense RIB for nuclear structure studies. Spiral II will have a low-energy area called DESIR (Decay Excitation Storage of Radioactive Ions). In order to optimize beam purity DESIR will include a high-resolution mass spectrometer ($m \sim 20\,000$) only if the (HRS). The HRS will reach its designed performances ($m/\text{mm mrad}$). To reduce the emittance from injected beam has an emittance of a few the SPIRAL II production source, ECR in most cases. Based on the different coolers we have developed and run we have designed a radiofrequency cooler able to handle intensities over $1\mu\text{A}$ [1]. The main difference with existing coolers is the beam intensities of about one micro amp, the radiofrequency voltage amplitude: over 10 kV at 10 MHz, as well as the rather severe radioactive environment in which the cooler will operate. We will present the status of the cooler including the most recent transmission and cooling results obtained on a prototype. Future plans and limitations will also be discussed.

THU-M1 — Thursday Morning Session 1

Status of the FAIR Project

Markus Steck - GSI

The Facility for Antiproton and Ion Research (FAIR) will provide high intensity primary beams which be used to a large extent for the production of secondary beams. Antiprotons will be produced by bombardment of a nickel target with 29 GeV protons, rare isotope beams (RIBs) will emerge from a second target where they are produced by fragmentation of a heavy ion beam. Cooling in the storage rings after the production targets is crucial in order to make the hot secondary beams available for experiments. Both stochastic and electron cooling are

foreseen. Stochastic cooling is used for pre-cooling of antiprotons and RIBs, electron cooling will provide high quality beams for internal and external experiments and will increase the efficiency of deceleration of secondary beams. The establishment of a new company owned by international partners is a pre-requisite for the start of the project, The status of the machine design and of the preparations to start the project will be reported.

Tevatron Electron Lens and It's Applications

Xiaolong Zhang - Fermilab

The Tevatron Electron Lens (TEL) is designed for the purpose of the Beam-beam tuneshift compensation. Now it's one of the vital part of the Tevatron. In this report, its daily operations and beam study results are presented. And its possible future applications are also discussed as well.

Electron cooling force measurements with variable profile electron beam in HIRFL-CSRm

Lijun Mao - IMP

A new generation of electron cooling device has been operated in HIRFL-CSRm, in which the variable profile electron beam was used. The most important characteristics of the electron cooling device are the attainable values of the cooling force as well as the dependencies of the cooling force on electron parameters. In order to demonstrate the advantage of this electron cooling device, the longitudinal cooling force has been measured for $^{12}\text{C}^{6+}$ ions at energy of 7.0 MeV/u, 200MeV/u, 400MeV/u and $^{36}\text{Ar}^{18+}$ ions at energy of 21.6 MeV/u, by electron energy-step method. Measurements for different electron beam currents and profiles are presented which show that longitudinal cooling force is function of the density at center of electron beam, and for hollow electron beam decreasing density at center results for decreasing longitudinal cooling force. Moreover, parameter dependence on the alignment angles between the ion and electron beam was investigated.

THU-M2 — Thursday Morning Session 2

Transfer of CRYRING to FAIR

Håkan Danared - MSL

The CRYRING synchrotron and storage ring at the Manne Siegbahn Laboratory will be transferred to the new FAIR facility in Darmstadt, where it will be used for cooling and deceleration of antiprotons and heavy ions at FLAIR. There, the ring will decelerate antiprotons from 30 MeV kinetic energy to 300 keV, and ions will be decelerated through the same range of magnetic rigidities. Before transfer, new injection and extraction systems will be designed and partially tested. The new injection system will combine multiturn injection from a dedicated low-energy injector and fast injection of particles from the NESR ring. Both fast single-turn extraction and slow resonant extraction will be implemented. An electrostatic septum is being built, and extraction tests with cooled proton beams will be performed during the autumn of 2009. The paper will describe modifications and preparations

for the transfer of CRYRING to FAIR.

The Versatile NESR Storage Ring With Powerful Electron Cooling

Christina Dimopoulou - GSI

The large-acceptance New Experimental Storage Ring (NESR) at FAIR has two main operation modes: storage of ion beams for internal experiments and deceleration of highly charged ions and antiprotons before transfer to a low-energy area. The heavy ion beams can be stable or rare isotopes selected in a magnetic separator. Antiprotons come at 3 GeV from the production target, they are stochastically pre-cooled and accumulated in a dedicated complex. The NESR operation relies on a performant electron cooler designed for up to 500 keV electron energy, 2 A electron current and with the option of magnetic expansion/compression. Electron cooling provides highest phase-space density of the stored beams and compensates beam diffusion during deceleration so that high efficiency can be reached. For low-abundant isotopes, it also supports the longitudinal RF-accumulation, e.g. by means of barrier bucket pulses. For short-lived isotopes the cooling and deceleration time is optimized to a few seconds. Selected results of beam dynamics studies and benchmarking experiments from the existing ESR are presented in connection with the requirements of the users.

Ultra low energy electron cooler for the Heidelberg CSR

Andrey Shornikov - MPI-K

As a part of the low energy electrostatic Cryogenic ion Storage Ring (CSR) an ultra low energy electron cooler is under construction at the MPI-K in Heidelberg. The device is intended to provide both phase space cooling and cold electrons for recombination merged beam experiments at electron laboratory energies from 160 eV down to a fraction of eV. To achieve the beam quality required for electron cooling at such low energies we plan to use the cryogenic photocathode electron source* together with a merging scheme and a decelerating electron optics suitable for both low energy electrons and slow ions of different masses from 1 to 160-200 a.m.u at 300keV kinetic energy. The cooler shares the basic design concept of the CSR with two level vacuum system. The first level is an isolation vacuum and the second one is the 2K cryo-pumped beam XUHV vacuum volume with ~ 1000 rest gas particles per cubic cm. Most of essential parts of the cooler including magnet system will be installed inside of the isolation vacuum chamber. In this paper we present mechanical and cryogenic design of the CSR electron cooler as well as some recent experimental results on ultralow energy electron beams.

THU-A1 — Thursday Afternoon Poster Session

Prototype Pick-up Tank for CR Stochastic Cooling at FAIR

Fritz Nolden - GSI

A prototype pick-up tank for stochastic precooling in the CR storage ring of the FAIR project at GSI was built. It is equipped with movable electrodes driven by linear motors. The

electrodes can be operated at cryogenic temperatures. The design of the tank and first test measurements are presented.

Numerical Analysis of Low-Intensity Schottky Spectra Recorded as Time Series

Fritz Nolden - GSI

Schottky spectra of extremely well cooled low-intensity ion beams suffer from a low signal-to-noise ratio. Their digital post-processing is neither well prescribed nor trivial. The paper presents a comparison of the use of Hanning windows with overlapping samples on one hand, and of multitaper analysis, on the other hand. It is shown that the area under the Schottky peak is better defined if the multitaper method is used.

Effective Luminosity Simulation for PANDA Experiment at FAIR

Alexander V. Smirnov - JINR

One of the ways to achieve the design luminosity value for PANDA experiment is to use a pellet target. However, such target is coming up with the short-scale luminosity variation. Peak to mean luminosity ratio can reach a big value unacceptable for detectors. Especially for PANDA experiment an additional algorithm was developed and implemented into the BETACOOOL. A numerical simulation is connected to two different time-scale processes. The first one is the short-time process (about tenths microsecond long) which describes luminosity variations while one pellet is crossing the beam. The second long-time process of the beam parameter evolution (particle number, transverse and longitudinal profiles) are defined by the beam losses and equilibrium between the target heating and electron cooling. Results of the simulation show that for the high luminosity mode the effective luminosity can be equal to the mean luminosity if the pellet size is less than 0,02 mm and the detector limit in one order larger then average one. For the high luminosity mode the using of the pellet target can lead to the very large reduction of the effective luminosity.

Prototype Pick-up Module for CR Stochastic Cooling at FAIR

Claudius Peschke - GSI

The performance of the Collector Ring (CR) of the FAIR project will strongly depend on a stochastic cooling system which is designed for fast pre-cooling of rare isotope and antiproton beams injected at different velocities. A prototype of the cryogenic movable pick-up module has been built. It consists of four circuit boards on an aluminum body and includes two times eight slotline electrodes, combiners and test electronics. It has been optimized for high sensitivity and flat frequency response. Measurements of the electric near-field over frequency and position will be presented.

Calculations of Electron Beam Motion in Electron Cooling System for COSY

Maxim Igorevich Bryzgunov - BINP SB RAS

Results of calculations of electron beam motion in cooler for COSY (Juelich, Germany) are shown. The aim of the calculations is to study excitation of the beam galloping due to magnetic and electric field ripples, imperfection of bending field in toroids, transverse electric

field in the end of accelerating tube. Dependences of the beam temperature on different parameters of magnetic and electrostatic systems are presented. Methods of correction of electron beam motion in order to decrease its transverse velocity are shown.

Simulation Study of Simultaneous Use of Stochastic Cooling and Electron Cooling with Internal Target at COSY and HESR

Takeshi Katayama - GSI

The small momentum spread of proton beam has to be realized and kept in the storage ring during the experiment with dense internal target such as pellet target. The stochastic cooling alone can not compensate the mean energy loss by the internal target, and the barrier bucket cavity will help this energy loss. In addition the further small momentum spread could be realized with use of electron cooling. In the present study, the simulation results on the simultaneous use of stochastic cooling and electron cooling at COSY 2GeV proton, and HESR 5GeV proton are presented.

Implementation of longitudinal dynamics with barrier RF in Betacool and comparison to ESME

Alexander V. Smirnov - JINR

The barrier bucket RF system is successfully used a few years on Recycler storage ring at Fermilab. The special program code ESME was elaborated for the numerical simulation of the manipulation with particles in the longitudinal phase space. This program helps to optimize of Recycler regimes and to increase the luminosity in the colliding experiments. The electron and stochastic cooling decrease of the phase space in all degree of freedom. In the case of the small phase space volume the intrabeam scattering brings couple between transverse and longitudinal temperature of the antiproton beam. For the numerical simulation of cooling processes at Recycler the new model of the barrier bucket was implemented in the BETACOOOL code. The comparison between ESME and BETACOOOL codes for the stationary and moving barrier buckets is presented.

Advance in the LEPTA Project

Andriy Kobets - JINR

The Low Energy Positron Toroidal Accumulator (LEPTA) at JINR is close to be commissioned with circulating positron beam. The LEPTA facility is a small positron storage ring equipped with the electron cooling system and positron injector. The maximum positron energy is of 10 keV. The main goal of the project is generation of intensive flux of Positronium (Ps) atoms ζ the bound state of electron and positron and setting up experiments on Ps in-flight. The report presents an advance in the project: up-grade of LEPTA ring magnetic system, construction of positron transfer channel, commissioning of the electron cooling system and first results of low energy positron formation and storage with ^{22}Na radioactive positron source of radioactivity of 25 mCi.

Muon cooling in a racetrack FFAG using superfluid helium wedge absorbers

Akira Sato - Osaka University

An FFAG lattice with racetrack-shape has been designed to cool muon beams. The ring has straight sections with FFAG magnets. Wedge absorbers using superfluid helium and RF cavities are installed to the straight section. This paper describes the first result of simulation study.

Wedge Absorber Simulations For The Muon Ionization Cooling Experiment

Pavel Snopok - UCR

In the Muon Ionization Cooling Experiment (MICE), muons are cooled by ionization cooling. Muons are passed through material, reducing the total momentum of the beam. This results in a decrease in transverse emittance and an increase in longitudinal emittance, but overall reduction of 6D beam emittance. In emittance exchange, a dispersive beam is passed through wedge-shaped absorbers. Muons with higher energy pass through more material, resulting in a reduction in longitudinal emittance as well as transverse emittance. In this paper, we consider two methods for demonstrating emittance exchange in MICE. In the first instance a muon beam is passed through a wedge shaped absorber; the input beam must be carefully selected to accommodate strong non-linear effects due to chromatic aberrations in the solenoid lattice. In the second instance, a less careful selection of the beam is necessary, but instead non-linear effects are offset by using an intricately shaped absorber.

Cooling Stacking Experiments at HIMAC

Toshiyuki Shirai - NIRS

The 11C beam acceleration has been studied in order to form and verify a three-dimensional irradiation field for cancer radiotherapy at HIMAC. In the project, the 11C beam is generated from the frozen $^{11}\text{CO}_2$ in the ion source and injected to HIMAC synchrotron through the linac. The cooling stacking technique plays an important role because of the low intensity of 11C (several 10^7 /injection). The numerical target of the stored 11C is 109 in the ring, which is a sufficient number to irradiate a single slice in the scanning irradiation method. The issues of the cooling stacking at HIMAC are the cooling time and the coherent instability. The cooling time of the multi-turn injected 12C beam has been shortened to 2 seconds by some improvements. The coherent instability can be suppressed by the digital beam feedback system. The stacking of 109 particles can be achieved with the feedback. The possibility of the 11C stacking at HIMAC will be discussed from the simulation and the experimental results.

Application of BPM in HIRFL-CSR Electron cooler

Guohong Li - IMP

In order to measure the positions of ion beam and electron beam at the same time, two sets of capacitive cylinder beam position monitors were installed in the two ends of electron cooling section. The NI-5105 (8 channel High-Density Digitizer) was adopted as main data acquisition and the data was processed by the special code of LabView. With the help of these systems, the positions of electron beam and ion beam was measured during the process of accumulation and acceleration. The movement of drag force was observed in the case of different relative position (angle).

Study on the Oxide Cathode for HIRFL-CSR Electron cooler

Xiaoxia Wang - Institute of Electronics

The oxide cathode is still the most widely used in vacuum electronic devices as electron sources. With the ongoing development of electronic devices, the requirements for the emission characteristics of the cathode have to be enhanced to suit the new applications. It is new research directions for oxide cathode that is put forward to not only remain its characteristics of low operation temperature and simple manufacture technique but also enhance the properties such as DC and PC emission current. This paper studied the manufacture technique and properties for oxide cathode and their emission mechanism. Then a new type of oxide cathode is developed and tested its DC emission properties and lifetime. The emission characteristics of the cathode is better than that of conventional oxide cathode. Part of properties of the cathode used in HIRFL-CSR Electron cooler is tested. In addition the oxide cathode is demonstrated research potential and may be candidate for considerable applications.

The primary plan of stochastic cooling at HIRFL-CSR

Junxia Wu - IMP

The primary plan of stochastic cooling at HIRFL-CSR

THU-A2 — Thursday Afternoon Teatime Talk

Physics with stored and cooled ion beam at HIRFL-CSR

Hushan Xu – IMP

Abstract text to be submitted by the author.

The evolution of the phase space density of particle beams in external fields

Evgeniy Grigorievich Bessonov - LPI

The evolution of the phase space density of particle beams in external fields is calculated in the general case proceeding from the continuity equation in the six-dimensional phase space *. The Robinson theorem, which includes the Liouville theorem as a special case, is reconsidered.

FRI-M1 — Friday Morning Session 1

Electron cooling for the therapy acceleration complex

Vasily Parkhomchuk - BINP SB RAS

Institute of Nuclear Physics (BINP, Novosibirsk) development the new therapy accelerator system based on the using electron cooling. The electron cooling will use for beam accumulation by the repeated injection at the main ring from the fast cycling booster synchrotron. After acceleration the carbon beam to 200-400 MeV/u the electron cooling will

use for shrink the emittances to minimal and for extraction and distribution the small fractions of ion beam according program irradiation. At report discussed extraction systems base on the electron cooling. The computer simulation illustrated the experimental results of the electron cooling at CSRe at time of commissioning.

Electron Cooling in CSRe

Xiaodong Yang - IMP

The 400MeV/u $^{12}\text{C}^{6+}$ ion beam was successfully cooled by the intensive electron beam near 1 Ampere in CSRe. The momentum cooling time was estimated near 15 seconds. The cooling force was measured in the cases of different electron beam profiles, and the different angles between ion beam and electron beam. The lifetime of ion beam in CSRe was over 80 hours. The dispersion in the cooling section was confirmed as positive close to zero. The beam sizes before cooling and after cooling were measured by the moving screen. The beam diameter after cooling was about 1 millimeter. The bunch length was measured with the help of BPM signals. The diffusion was studied in the absent of electron beam.

Status of the 2 MeV Electron Cooler for COSY Juelich

Juergen Dietrich - FZJ

The design, construction and installation of a 2 MeV electron cooling system for COSY-Juelich is proposed to further boost the luminosity even with strong heating effects of high-density internal targets. In addition the 2 MeV electron cooler for COSY is intended to test some new features of the high energy electron cooler for HESR at FAIR in Darmstadt. The design of the 2 MeV electron cooler will be accomplished in cooperation with the Budker Institute of Nuclear Physics in Novosibirsk, Russia. A new developed prototype of the high voltage section, consisting of a gas turbine, magnetic coils and high voltage generator with electronics was successfully tested . Special emphasis is given to a voltage stability better than 10^{-4} . First experiments with three combined high voltage sections, arranged in a SF₆ pressurized gas tank are reported.

FRM2 — Friday Morning Session 2

Coherent electron cooling

Vladimir N. Litvinenko - BNL

Cooling intense high-energy hadron beams remains a major challenge in modern accelerator physics. Synchrotron radiation is still too feeble, while the efficiency of two other cooling methods, stochastic and electron, falls rapidly either at high bunch intensities (i.e. stochastic of protons) or at high energies (e-cooling). In this talk a specific scheme of a unique cooling technique, Coherent Electron Cooling, will be discussed. The idea of coherent electron cooling using electron beam instabilities was suggested by Derbenev in the early 1980s, but the scheme presented in this talk, with cooling times under an hour for 7 TeV protons in the LHC, would be possible only with present-day accelerator technology. This talk will discuss the principles and the main limitations of the Coherent Electron Cooling process. The talk

will describe the main system components, based on a high-gain free electron laser driven by an energy recovery linac, and will present some numerical examples for ions and protons in RHIC and the LHC and for electron-hadron options for these colliders. BNL plans a demonstration of the idea in the near future.

Status of the HIRFL-CSR Project

Youjin Yuan – IMP

Abstract text to be submitted by the author.

Electron Cooling for Future EIC at Jefferson Laboratory*

Yaroslav Derbenev - JLAB

A conceptual design of a polarized ring-ring electron-ion collider (ELIC) with luminosity up to 10^{35} cm⁻²s⁻¹ in nucleon energy range from 5 up to 250 GeV and electron energy 3-11 GeV based on the 12 GeV CEBAF has been developed at the Jefferson Lab. An inevitable component of this collider is high energy electron cooling (EC) of ion beams. The cooling facility consists of a 30 mA, 125 MeV energy recovery linac (ERL) and 3 A circulator-cooler ring (CCR) operated at 15 and 1500 MHz bunch repetition rate respectively. Fast kicker has been designed for switching e-bunches between the ERL and CCR. This cooling facility can also be operated at low nucleon energies. To alleviate the space charge impact on cooling and luminosity, we developed a concept of helical EC, in which ion beam is round and has a large size but low 4D emittance, by matching the circular eigen modes of the ion ring with strong solenoid of cooling section. The collider luminosity is restored by transforming the round ion beam to a flat one in collision area. The design parameters of this cooling facility and scenario of forming and cooling of ion beam will be presented.