COOL'25 - the 15th International Workshop on Beam Cooling and Related Topics

Sunday 26 October 2025 - Friday 31 October 2025

Wang Center

Book of Abstracts

Contents

High-Energy Cooling Applications I / 7

Hadron Beam Cooling Concept and Cooler Design Status for the EIC

Authors: Alexei Fedotov[1]; Dmitry Kayran[1]; Sergei Seletskiy[1]

[1] *Brookhaven National Laboratory*

Cooling of hadrons in Electron Ion Collider (EIC) is critical to achieve EIC design parameters and performance. In this talk we will discuss strategy of hadron beam cooling application for the EIC starting with providing strong cooling of proton beam emittances at injection energy of 24 GeV and potential subsequent cooling at the top collision energies. We will then discuss requirements, challenges and design status of RF-based electron cooler for 24 GeV proton energy.

Footnotes:

Work supported by the U.S. Department of Energy.

Funding Agency:

I have read and accept the Privacy Policy Statement:

Yes

Cooler Designs and Applications I / 8

Multiple-Slice Simulations of Coherent Electron Cooling Performance with Low Beam Current

Author: Jun Ma[1]

Co-authors: Gang Wang [1]; Vladimir Litvinenko [2]; Yichao Jing [1]

[1] *Brookhaven National Laboratory*

[2] *Stony Brook University*

Coherent electron cooling (CeC) is a novel technique for rapidly cooling high-energy, high-intensity hadron beam. Plasma cascade amplifier (PCA) has been proposed for the CeC experiment in the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL). Cooling performance of PCA based CeC has been predicted in 3D start-to-end CeC simulations using code SPACE for multiple slices in the beam. The operation of low beam current provides more flexibilities for the CeC experiment.

Footnotes:

Funding Agency:

Work supported by Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the U.S. Department of Energy.

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Yes

Cooling Studies and Reports / 9

Simulation of Longitudinal Electron Cooling of 20 GeV Proton Beam at EicC

Author: Xiaodong Yang[1]

Co-author: He Zhao [2]

[1] *Institute of Modern Physics, Chinese Academy of Sciences*

[2] *Institute of Modern Physics*

The longitudinal electron cooling processes of a 20 GeV proton beam were simulated using a code at the Electron-Ion collider in China. The longitudinal cooling time was obtained for different parameter configurations of the storage ring, proton beam, electron cooling device, and electron beam. From the simulated results, the longi-tudinal cooling time of the 20 GeV proton beam is over 100 seconds. The longitudinal cooling time can be short-ened with the help of proper configuration of the pa-rameters.

Footnotes:

Funding Agency:

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Yes

Facilities and Programs Session I / 10

Review of Ionization Cooling

Author: Katsuya Yonehara[1]

[1] *Fermi National Accelerator Laboratory*

Ionization cooling is a key concept for reducing beam emittance within muon lifetime and has been developed and experimentally demonstrated over the past three decades. These studies have highlighted important constraints and design challenges for practical cooling channels. Following the recommendations from the latest P5, collaboration with the IMCC has been encouraged, resuming efforts toward designing a viable muon collider. In this presentation, we provide a comprehensive review of previous studies on ionization cooling, discuss the identified constraints on ionization cooling channel designs, and introduce a few novel cooling concepts which potentially overcome these limitations.

Footnotes:

Funding Agency:

This work was produced by Fermi Forward Discovery Group, LLC under Contract No. 89243024CSC000002 with the U.S. Department of Energy, Office of Science, Office of High Energy Physics. Publisher acknow

I have read and accept the Privacy Policy Statement:

Yes

Laser Cooling Facilities Session / 12

High power optical cavities for ion beam cooling at the SPS Gamma Factory Proof of principle experiment

Author: Aurélien Martens[1]

[1] *Université Paris-Saclay, CNRS/IN2P3, IJCLab*

The Gamma Factory is a project which aims providing unprecedented rates of photons in a wide range of energy, possibly up to 400MeV. It relies on resonant atomic excitation of partially stripped ions accelerated at high energies with state of the art high power laser systems enhanced in optical resonators. In a proof of principle experiment at the CERN SPS, a demonstration of the viability of the technology is aimed at with the goal to realize laser assisted ion beam cooling. A status report on the project implementation will be given with strong emphasis on the recent demonstration of >700kW stacked in an optical cavity.

Footnotes:

- PBC-acc-GammaFactory-SPSpop@cern.ch

Funding Agency:

TheauthorsacknowledgethesupportoftheCERNPhysicsBeyondCollider
initiative.

I have read and accept the Privacy Policy Statement:

Yes

High-Energy Cooling Applications II / 13

Stochastic Cooling for the EIC

Author: Michael Blaskiewicz[1]

[1] *Brookhaven National Laboratory*

The Electron Ion Collider (EIC) will collide protons and heavy ions with electrons to study nonlinear interactions in QCD. Stochastic cooling will benefit the heavy ion luminosity. This talk will discuss the cooling system design and estimate the benefits of the cooling system.

Footnotes:

Funding Agency:

United States Department of Energy

I have read and accept the Privacy Policy Statement:

Yes

Cooling Technology / 14

Versatile Platform for Relativistic Electron Cooling and Other Experiments

Author: Kurt Aulenbacher[1]

[1] *Helmholtz Institute Mainz*

At Helmholtz Insitute Mainz (HIM) a high voltage platform for high intensity electron beams has been installed. This apparatus is intended as a scalable, modular system for high energy magnetized DC-beam cooling. On the one hand, the system can be used as a prottype for antiproton beam cooling for the planned HESR storage ring at FAIR. On the other hand, because the HESR will be delayed, we have the opportunity to use the device for other applications. We present recently realized technial progress and how these can be applied for different new experiments during the time until the initially intended application becomes possible.

Footnotes:

Funding Agency:

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Yes

Facilities and Programs Session II / 15

Development of an electron cooler for HIAF facility in China

Author: Lijun Mao[1]

[1] *Institute of Modern Physics*

The High Intensity heavy-ion Accelerator Facility (HIAF) is a mega-scientific facility in China. A magnetized electron cooling system is used in the Spectrometer Ring (SRing) to improve the beam quality for internal target experiments. The maximum electron beam energy is up to 450 keV. In 2025, all components of the cooler have been installed in the SRing tunnel. In this report, the measurement of the longitudinal magnetic field quality, the test results of the high voltage system and the electron beam commissioning are reported.

Footnotes:

Funding Agency:

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Yes

High-Energy Cooling Applications I / 16

EIC Luminosity Models for Various Hadron Cooling Scenarios

Author: William Bergan[1]

[1] *Brookhaven National Laboratory*

We have developed a simulation to model the evolution of proton and gold bunches stored in the Electron-Ion Collider's Hadron Storage Ring (HSR) over the course of several hours, taking into account intrabeam scattering, the beam-beam effect, and particle loss. This has enabled us to predict how various cooling schemes, including microbunched electron cooling and microwave stochastic cooling, would impact the collider's luminosity. We discuss the details of this code and show the luminosity evolution for various scenarios.

Footnotes:

Funding Agency:

This work was supported by Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the U.S. Department of Energy.

I have read and accept the Privacy Policy Statement:

Yes

Laser Cooling Session / **17**

Challenges of Laser Cooling at SIS100: UV Systems and Overlap in 5D

Author: Denise Schwarz[1]

Co-authors: Jens Gumm [1]; Benedikt Langfeld [1]; Tamina Grunwitz [1]; Sebastian Klammes [2]; Danyal Winters [2]; Thomas Walther [1]

[1] *Technical University of Darmstadt*

[2] *GSI Helmholtz Centre for Heavy Ion Research*

Relativistic ion beams with a narrow momentum distribution are crucial for high-precision experiments at accelerator facilities. Laser cooling offers a promising approach to further reduce the momentum spread, thereby enhancing the ion beam quality. Previous experiments conducted at the Experimental Storage Ring (ESR) at GSI have demonstrated the efficiency of both continuous-wave (cw) and pulsed UV lasers in achieving this goal. By using three laser systems, the cooling efficiency can be further improved.

This work presents a continuous-wave laser system operating at a wavelength of $257.24\,\mathrm{nm}$, enabled by two second-harmonic generation stages. Particularly, long-term operation with high UV output power is of great interest. By employing elliptical focusing in the second enhancement cavity, a long term stable UV output power up to $2\,\mathrm{W}$ is achieved, providing an efficient solution for ion beam cooling. The integration of this cw laser and two pulsed laser systems at the SIS100 of FAIR requires the optimization of the spatial, temporal, and energy overlap between the three laser beams and the ion beam.

Footnotes:

Funding Agency:

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Yes

Cooling Studies and Reports / 18

Electron and Laser Cooling of Stored Ion Beams at CERN: XSuite Simulations and Measurements

Author: Davide Gamba[1]

Co-author: Peter Kruyt [1]

[1] *European Organization for Nuclear Research*

Electron and laser cooling are key techniques for improving the quality of stored ion beams in synchrotrons. This work presents simulations performed with XSuite to study electron and laser cooling in various CERN machines. The electron cooling simulations, based on the Parkhomchuk model recently implemented in XSuite, are benchmarked against existing codes. The laser cooling studies investigate the feasibility of implementing this technique in the CERN SPS, either to enhance ion beam brightness or as a step toward a potential Gamma Factory in the LHC. Additionally, an overview of experimental electron cooling measurements from various CERN facilities is presented, providing insights into the agreement between model predictions and observed cooling performance.

Footnotes:

Funding Agency:

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Yes

Facilities and Programs Session II / 19

Cooling Demonstrator Program for the Muon Collider

Author: Diktys Stratakis[1]

[1] *Fermi National Accelerator Laboratory*

A multi-TeV Muon Collider (MuC) has the unique potential to provide both precision measurements and the highest energy reach in one machine that cannot be paralleled by any currently available technology. One of the key challenges in development of the MuC is delivery of a high brightness muon beam, which is essential to produce sufficient luminosity. Ionization cooling, is currently the only feasible option for cooling a muon beam. Although MICE proved the physics principles of ionization cooling, the challenges associated with the cooling technology and its integration remain the bottleneck for a MuC. To understand and mitigate these risks, a Demonstrator facility that contains a sequence of ionization cooling cells that closely resemble a realistic ionization cooling channel is required. Such a facility will not only allow the design of each component of a cooling cell but will also allow the integrated performance of these to be tested to demonstrate that there are no showstoppers for such systems. In this talk I will review the progress on design of the muon cooling Demonstrator. Then I will discuss potential host sites and associated timelines within which the Demonstrator could be deployed. Finally, I will identify associated science programs that could be synergistic with the development, construction and operation of the Demonstrator.

Footnotes:

Funding Agency:

I have read and accept the Privacy Policy Statement:

Yes

Laser Cooling Session / 20

UV Laser System(s) for Laser Cooling of Relativistic Bunched Ion Beams at the SIS100

Author: Tamina Grunwitz[1]

Co-authors: Benedikt Langfeld [1]; Danyal Winters [2]; Denise Schwarz [1]; Jens Gumm [1]; Sebastian Klammes [2]; Thomas Walther [1]

[1] *Technical University of Darmstadt*

[2] *GSI Helmholtz Centre for Heavy Ion Research*

Laser cooling is a promising technique to achieve a narrow momentum distribution of relativistic bunched ions in accelerators. This technique allows efficient cooling, especially for highly relativistic ion beams and heavy ions, with cooling times on the order of seconds. Previous experiments at the ESR have successfully demonstrated laser cooling of relativistic bunched ion beams with both a continuous wave (cw) and a pulsed laser system. For the efficient application of laser cooling at the new SIS100 facility at GSI FAIR, three laser systems will be used simultaneously to ensure optimal cooling.

Two high-power laser systems for laser cooling at the SIS100 are being developed at the TU Darmstadt: a cw and a pulsed laser system. The pulsed laser achieves a maximum UV output of up to 5 W with a tunable frequency range of over 3 THz around a center wavelength of 257.4 nm. The pulse duration can be varied between 50 to 735 ps, thus allowing a flexible width of the cooling force, while the adjustable repetition rate between 1 and 10 MHz provides easy synchronisation with the ion bunches. In a beam experiment with bunched $^{12}C^{3+}$ ions at the ESR Helmholtzzentrum GSI in 2021, laser cooling was successfully demonstrated employing this laser system.

Footnotes:

Funding Agency:

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Yes

Cooling Technology / 21

Progress Towards a Field Emission Electron Gun for the ELENA Electron Cooler

Author: Gerard Alain Tranquille[1]

Co-author: Elisabeth-Sena Welker [2]

[1] *European Organization for Nuclear Research*

[2] *European Organization for Nuclear Research; TU Wien*

Field emission-based cathodes have been shown to be an attractive alternative to thermionic sources for the generation of electron beams. Their low transverse energy spread, and low power consumption make them an ideal replacement for the thermionic cathode currently used on the electron cooler of the Extra Low ENergy Antiproton (ELENA) ring.
We have investigated the use of carbon nanotubes (CNT) as the field emitting source, studying the emission characteristics and lifetime of various patterned structures. Fowler-Norheim analysis of our samples has given us a better understanding of the limiting factors of such sources, especially the influence of the conditioning process on the emitted current.
A double-gridded electron gun has also been tested with CNT samples of various sizes up to 4x4 cm2. The measured current density for the larger samples was somewhat lower that expected and showed a larger beam divergence than what was predicted by the simulations. This discrepancy is currently under investigation as well as improvements to the gun design to obtain stable and reproducible beams.

Footnotes:

Funding Agency:

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Yes

Cooling Technology / 22

A Neutral Hydrogen Monitor for Electron Cooling Studies of H-Ions in ELENA

Author: Gerard Alain Tranquille[1]

[1] *European Organization for Nuclear Research*

H- ions are routinely used for the recommissioning of the ELENA ring as well as for various machine studies. Because of the weak binding energy of the electron, these ions are stripped by the interaction with the residual gas molecules and the intense electron beam generated by the electron cooler after which they are lost on the vacuum chambers of the main machine dipoles.
A neutral hydrogen monitor is installed downstream from the electron cooling device in the extension of one of the dipole magnets and is used to study the abovementioned effects. This provides much information on the evolution of the beam size and position in the cooling section during the deceleration as well as the performance of the electron cooler.

Footnotes:

Funding Agency:

I have read and accept the Privacy Policy Statement:

Yes

Advanced Cooling R&D Session / 24

Research and Development of an Ultrahigh Precision Single Ion Implanter

Author: Yosuke Yuri[1]

Co-authors: Kouichi Hosaka [1]; Nobumasa Miyawaki [1]; Seiji Hosoya [1]; Yasuyuki Ishii [1]; Hirotsugu Kashiwagi [1]; Ryohei Yamagata [1]; Kazumasa Narumi [1]; Shinobu Onoda [1]; Kento Muroo [2]; Kiyokazu Ito [2]; Hiromi Okamoto [2]

[1] *National Institutes for Quantum Science and Technology*

[2] *Hiroshima University*

Ion implantation is an accelerator technology essential for creating defects or introducing impurities into materials. A research and development study is currently underway at QST Takasaki Institute toward ultrahigh-precision single-ion implantation based on laser-cooling techniques. To achieve this, we incorporate a linear Paul trap as an ultracold single-ion source, where trapped ions can be cooled to the order of mK or even "Coulomb-crystallized"by Doppler laser cooling. In our scheme, N or Si ions, useful for ion implantation to create color centers, are sympathetically cooled down to the mK range through Coulomb collisions by co-trapping them with laser-cooled Ca ions. Then, the ions are extracted selectively from the trap to be accelerated and focused through a 50-kV electrostatic bipotential lens system. We aim to focus the ions on the order of 10 nm for ultrahigh-precision implantation. The implantation system has already been assembled, and the commissioning is currently underway to enable ion extraction using a Coulomb crystal and focusing extracted cold ions. We present the status of system development and outline the scheme for selective ion extraction and nanobeam focusing based on multiparticle simulations.

Footnotes:

Funding Agency:

Work supported in part by JST Moonshot R&D Grant Number JPMJMS2062 and JSPS KAKENHI Grant Numbers JP25K15770.

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Yes

Advanced Cooling Applications / 25

Proposed Ultralow-Emittance Beam Source for High-Luminosity Hadron Colliders

Author: Stephen Brooks[1]

[1] *Brookhaven National Laboratory*

Laser Doppler cooling of ion bunches in a Paul trap is a demonstrated method of achieving millikelvin bunch temperatures, with the ions forming a Coulomb crystal with a solid-like structure. This is proposed as a source for accelerators that would be a factor 10^5 lower in emittance than conventional plasma sources. Methods to transport the crystalline bunch while limiting emittance growth are examined, including a novel ring in which the bunch maintains a fixed orientation relative to the outside world (i.e. does not rotate with the ring as usual). In this geometry, magnetic focussing can confine all three dimensions of the bunch without RF. This ring can circulate a 3D crystalline bunch with heating rates of less than 1K/s.

Footnotes:

Funding Agency:

I have read and accept the Privacy Policy Statement:

Yes

High-Energy Cooling Applications II / 26

Development of Storage Ring Electron Cooler for High Energy Applications

Author: Sergei Seletskiy[1]

Co-authors: Alexei Fedotov [1]; Dmitry Kayran [1]; Georg Hoffstaetter [2]; Jonathan Unger [2]; Jorg Kewisch [1]; Yichao Jing [1]

[1] *Brookhaven National Laboratory*

[2] *Cornell University (CLASSE)*

Electron cooling at high energy requires large average current in the cooling section (CS), which can be achieved by reusing the same electron beam on many passes through the CS. One of the options to realize such a cooling scheme is to use an electron storage ring with electrons being cooled by dedicated radiation damping wigglers. We will discuss the conceptual design of the 150 MeV Ring Electron Cooler as a potential future application for the Electron Ion Collider.

Footnotes:

Funding Agency:

Work supported by Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the U.S. Department of Energy.

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Yes

Laser Cooling Facilities Session / 27

Laser cooling of antihydrogen atoms in the ALPHA trap

Author: Chris Rasmussen[1]

[1] *Brookhaven National Laboratory*

Antihydrogen - the bound state of an antiproton and a positron - is of great interest for tests of fundamental symmetries which compare antimatter to ordinary matter. In the ALPHA experiment these exotic atoms are confined in a magnetic minimum with a lifetime of many hours, limited only by annihilations on background gas in the vacuum chamber. This enables high precision measurements which require long interrogation times and where the lowest achievable sample temperature is desired.

Doppler cooling of the trapped antihydrogen atoms has been demonstrated with a single laser beam resulting in 3D cooling*. This is possible due to partial coupling of motional degrees of freedom in the confining potential. Complexity in the dynamics of the cooling process arise due to potentially disparate timescales of cooling along the laser axis and energy mixing in the trap.

In this talk I will present recent progress on laser cooling in ALPHA as well as its combination with adiabatic expansion cooling, which has produced the coldest antihydrogen samples to date.

Footnotes:

- Baker, C.J., Bertsche, W., Capra, A. et al. Laser cooling of antihydrogen atoms. Nature 592, 35–42 (2021)

Funding Agency:

I have read and accept the Privacy Policy Statement:

Yes

Advanced Cooling Applications / 28

Ion machine-gun experiment at Hiroshima University

Author: Kento Muroo[1]

Co-authors: Kiyokazu Ito [1]; Hiromi Okamoto [1]; Yosuke Yuri [2]; Nobumasa Miyawaki [2]

[1] *Hiroshima University*

[2] *National Institutes for Quantum Science and Technology*

Low-intensity ion beams with transverse dimensions of the order of microns or submicrons have been employed for a variety of purposes. In some advanced applications, however, the beam size needs to be even much smaller. One such example is the creation of color centers in diamond, which requires us to transport ions of specific species one by one to a target with nanometer precision. A possible approach to this challenging goal is the use of the so-called "ion machine gun (IMG)". The IMG is a unique ion source based on a compact "linear Paul trap"with a Doppler laser cooler. The Doppler cooling technique is so powerful that we can reduce the temperature of a stored ion cloud close to absolute zero where the ultracold ions establish a spatially ordered configuration called "Coulomb crystal". The normalized root-mean-squared emittance of a Coulomb crystal can be on a femtometer order, which opens up the possibility of attaining an extremely narrow "nanobeam" . At Hiroshima University, we have conducted a proof-of-principle study of this novel beam-source concept, using laser-coolable calcium ions and sympathetically cooled nitrogen ions in a prototype IMG. In this talk, an overview is given of recent results of numerical simulations and preliminary experiments.

Footnotes:

Funding Agency:

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Yes

Advanced Cooling R&D Session / 29

Results of the Coherent electron Cooling experiment at RHIC

Author: Vladimir Litvinenko[1]

[1] *Stony Brook University*

Coherent electron Cooling (CeC) experiment aims on demonstrating cooling of ion beam circulating in RHIC yellow ring. The experiment will end by the end of 2025, when RHIC operations stop for construction of Electron-Ion Collider. In this talk I will present summary of the CeC experiments with special focus won the use and the control of the broad-band micro-bunching Plasma Cascade Amplifier with bandwidth of 15 THz. I will also discuss connection of this experiment with the developing future proton beam cooler for Electron Ion Collider.

Footnotes:

Funding Agency:

This research was supported by the DE-SC0021426 award from the Office of Nuclear Physics and by Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the U.S. Department of Energy.

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Yes

Cooling Technology / 30

Gun and Collector Development on the Electron Cooler Test Stand (ECTS)

Author: Ghanshyambhai Khatri[1]

Co-authors: Alexandre Frassier [1]; Gerard Alain Tranquille [1]; Jean Cenede [1]; Adriana Rossi [1]

[1] *European Organization for Nuclear Research*

The electron cooler of the Antiproton Decelerator (AD) at CERN, that can operate with an electron beam of up to 2.4 A at 27 keV, is scheduled for replacement during the upcoming Long Shutdown 3 (LS3). A newly designed electron gun and collector—optimized for enhanced reliability, efficiency, and operational performance—are undergoing rigorous testing and validation at the dedicated Electron Cooler Test Stand (ECTS).
The new electron collector features a re-engineered cooling system, where the water circuit is fully decoupled from the vacuum environment, significantly reducing the risk of vacuum leaks. The new electron gun operates at high perveance in the range of 2.2 to 2.5 μP and employs a magnetic beam expansion by a factor of two. This expansion lowers the transverse temperature of the electron beam, thereby enhancing the cooling efficiency.
This talk will present the ongoing research, key design considerations, and the latest experimental results from the ECTS, contributing to the successful implementation of the new AD electron cooler.

Footnotes:

Funding Agency:

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Yes

Facilities and Programs Session I / 31

Design overview of the Electron Ion Collider

Author: Sergei Nagaitsev[1]

[1] *Brookhaven National Laboratory*

The Electron-Ion Collider (EIC), which is being designed by BNL, JLab and other partners, will be a particle accelerator that collides electrons with protons and nuclei to produce snapshots of those particles' internal structure. It will collide polarized high-energy electron beams with hadron beams in the center-of-mass energy range of 20-140 GeV. The electron beam, employed as a probe, will reveal the arrangement of the quarks and gluons that make up the protons and neutrons of nuclei. The EIC will allow us to study the "strong nuclear force", the role of gluons in the matter within and all around us, and the nature of particle spin. This talk will describe the Electron-Ion Collider design and construction at Brookhaven National Lab.

Footnotes:

Funding Agency:

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Yes

Facilities and Programs Session I / 32

The CERN Antimatter Factory: Performance and Perspectives

Author: Laurette Ponce[1]

Co-authors: Bertrand Lefort [1]; Bruno Dupuy [1]; Davide Gamba [1]; Lars Jorgensen [1]; Pierre Freyermuth [1]; Wolfgang Höfle [1]; Yann Dutheil [1]

[1] *European Organization for Nuclear Research*

Since the end of the CERN Long Shut down 2 (LS2), the Antimatter Factory consists of the old CERN Antiproton Decelerator (AD) to which has been added the Extra Low ENergy Antiproton (ELENA) decelerator, allowing to serve 100 keV antiprotons up to 4 experiments at each cycle, as compared to 5.3 MeV to a single experiment before LS2. The much lower extraction energy make it possible for the experiments to increase the number of trapped antiprotons with up to two orders of magnitude. Since 2021, first year of beam physics in the ELENA era, the performances of both machines are constantly improving, allowing to deliver twice the designed bunch intensity to the users. In this contribution, we will present the current status of the facility and review the main improvements that allowed record beam intensities to be delivered, with emphasis on the optimization of antiproton production and injection, progress made on the stochastic and electron cooling performanceFinally, we will conclude with the consolidation and upgrades planned for the coming years.

Footnotes:

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Yes

Cooler Designs and Applications I / 33

Electron Beam Dynamics Simulation in Coherent Electron Cooling

Author: Yichao Jing[1]

Co-authors: Alexei Fedotov [1]; Dmitry Kayran [1]; Gang Wang [1]; Igor Pinayev [1]; Jun Ma [1]; Nikhil Bachhawat [2]; Sergei Seletskiy [1]; Vladimir Litvinenko [2]

[1] *Brookhaven National Laboratory*

[2] *Stony Brook University*

New scheme with lower electron beam energy together with lower peak beam current has been proposed for the Coherent electron Cooling (CeC) proof of principle experiment in RHIC Run 25. Such new operation mode appears to be a better candidate in providing a high quality electron beam for cooling performance. We will present our results to achieve the low slice emittance/low slice energy spread electron beam and discuss the progress in achieving better uniformity in both average slice energy and slice peak current to minimize potential anti-cooling effect.

Footnotes:

Funding Agency:

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Yes

Cooler Designs and Applications I / 35

Simulation of the Ion Bunch in the Presence of the CeC for the New Energy Scheme

Authors: Gang Wang[1]; Igor Pinayev[1]; Jun Ma[1]; Vladimir Litvinenko[2]; Yichao Jing[1]

[1] *Brookhaven National Laboratory*

[2] *Stony Brook University*

For RHIC run 25, the beam energy of the Coherent Electron Cooling (CeC) experiment will be reduced to achieve better cooling performance. For the new scheme, the distribution of the cooling electrons is obtained from beam dynamics simulation using Impact-T. A 3D particle in cell (PIC) simulation code, SPACE, is then used to obtain the cooling force that depend both on the longitudinal and transverse location of the circulating ions. In this study, we track the ions in the presence of the cooling force and investigate how their distribution evolves during the cooling process.

Footnotes:

Funding Agency:

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Yes

Cooling Studies and Reports / 37

Understanding Schottky spectra of stored laser-cooled bunched ion beams - simulations & recent experimental results from the CSRe

Authors: HANBING WANG[1]; Dongyang Chen[2]; Weiqiang Wen[3]; Youjin Yuan[4]; Dacheng Zhang[5]; Zhongkui Huang[3]; Danyal Winters[6]; Sebastian Klammes[6]; Daniel Kiefer[7]; Thomas Walther[7]; Markus Loeser[8]; Matthias Siebold[8]; Ulrich Schramm[9]; Junxia Wu[3]; Lijun Mao[3]; Jiancheng Yang[3]; Shaofeng Zhang[3]; Michael Bussmann[10]; Xinwen Ma[3]

[1] *Institute of Modern Physics*

[2] *Peking University*

[3] *Institute of Modern Physics; University of Chinese Academy of Sciences*

[4] *University of Chinese Academy of Sciences*

[5] *Xidian University*

[6] *GSI Helmholtz Centre for Heavy Ion Research*

[7] *Technical University of Darmstadt*

[8] *Helmholtz-Zentrum Dresden-Rossendorf*

[9] *Helmholtz-Zentrum Dresden-Rossendorf; Technische Universität Dresden*

[10] *Helmholtz-Zentrum Dresden-Rossendorf; Center for Advanced Systems Understanding*

Laser cooling of O5+ ion beams with an energy of 275.7 MeV/u was successfully achieved at the storage ring CSRe in Lanzhou, China. *The longitudinal momentum spread of the laser-cooled O5+ ion beams measured by the Schottky resonator reached Δp/p ≈ 2×10−6, which is limited by the resolution of the Schottky diagnostics for bunched ion beams. To interpret the experimental observations, a multi-particle tracking method has been developed to simulate the longitudinal Schottky spectra of bunched ion beams.*
*We systematically studied the dependence of the Schottky power on the number of stored ions. The Schottky power of the central peak is proportional to the square of the number of ions and coherently enlarged only when the observation frequency is an integer multiple of the bunching frequency. Otherwise, the Schottky power of the central peak and sidebands is proportional to the number of ions. Therefore, the greatly enhanced central peak, caused by the 'coherent effect', has been fully interpreted. Besides, we propose a novel method to extract the momentum distribution from the Schottky spectrum of the bunched ion beams by calculating the envelope of the total Schottky power of each sideband. Unlike the previously used methods**, this is a very simple and precise way for real-time monitoring of the momentum distribution during beam cooling experiments at the storage rings. We will present these results at the COOL'25 Workshop.

Footnotes:

- W. Q. Wen, et al., PRA 110 (2024) L010803. ** M. Bussmann, Proceedings of COOL 2007, 226-229; K. Lasocha, PRAB 23 (2020) 062803; V. Balbekov, Proceedings of EPAC 2004, Lucerne, Switzerland.

Funding Agency:

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Yes

Facilities and Programs Session II / 38

Generation of a cooled muon beam for the J-PARC muon g-2/EDM experiment

Author: Kazuhito Suzuki[1]

[1] *Nagoya University*

The J-PARC muon g-2/EDM experiment aims to measure the muon magnetic moment anomaly (a_μ = (g-2)/2) and to search for the muon electric dipole moment (EDM), with sensitivity comparable to the highest in the world. This will be achieved using a small-emittance muon beam, created by cooling muons to thermal energy at room temperature and accelerating them with a four-stage linac. The small emittance can eliminate the strong focusing requirements for muon storage and the beam-momentum constraint associated with the focusing, both adopted in the previous measurements conducted in BNL E821 and Fermilab E989. As a result, the J-PARC measurement has the experimental approach significantly different from that of the previous measurements, and will enhance our experimental understanding of a_μ and its deviation from theoretical predictions. The experiment, planned to begin commissioning in JFY2030, is currently progressing with the development and implementation of experimental instruments and facility construction. Notably, the first-stage acceleration of cooled muons, up to the kinetic energy of 100 keV, was successfully demonstrated at J-PARC in JFY2024. The obtained transverse emittance indicates more than two orders of magnitude reduction from that of muons before cooling. This talk will present the current status and future prospects of the experiment focusing on the development of the small-emittance muon beam.

Footnotes:

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Cooling Technology / 39

Beam Position Monitoring for Low Energy Cooling Section

Author: Igor Pinayev[1]

Co-author: Sergei Seletskiy [1]

[1] *Brookhaven National Laboratory*

Electron-Ion Collider will employ electron cooling of protons at the injection energy. To reduce the space charge effects, the RF system will be set to produce flat top proton bunches with reduced peak current. There will be three electron bunches per proton bunch separated by 5 nanoseconds. Electronics for the electron beam can be based on a conventional narrow-band processing at 394 or 591 MHz frequency. But the receivers for the proton beam are more demanding since we want to support their operation at store energy as well where bunch repetition rate can increase to 98.5 MHz. In this paper the technical solution as well as cross calibration of two systems are presented.

Footnotes:

Funding Agency:

Work supported by Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the U.S. Department of Energy.

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Cooler Designs and Applications II / 40

Design of a Microbunched Electron Cooler Energy Recovery Linac

Authors: Bamunuvita Gamage[1]; Christopher Mayes[2]; Colwyn Gulliford[3]; Derong Xu[4]; Dmitry Kayran[4]; Erdong Wang[4]; Isurumali Neththikumara[1]; Jiquan Guo[1]; Karl Smolenski[3]; Kirsten Deitrick[1]; Nicholas Sereno[5]; Nicholas Taylor[3]; Ningdong Wang[6]; Robert Rimmer[1]; Sadiq Setiniyaz[1]; Stephen Benson[1]; William Bergan[4]

[1] *Thomas Jefferson National Accelerator Facility*

[2] *SLAC National Accelerator Laboratory*

[3] *Xelera Research (United States)*

[4] *Brookhaven National Laboratory*

[5] *Argonne National Laboratory*

[6] *Cornell University*

Microbunched electron Cooling (MBEC), a type of Coherent electron Cooling (CeC), is a possible way to cool high energy protons; such an electron cooler can be driven by an energy recovery linac (ERL). The beam parameters of this design are based on cooling 275 and 100 GeV protons at the Electron-Ion Collider (EIC), requiring 150 and 55 MeV electrons, respectively. If implemented, a high energy cooler would serve to increase the average luminosity of the collider by mitigating the emittance growth caused by various processes. This ERL is designed to deliver a bunch charge of 1 nC, an average current of 100 mA, and strict requirements on the transverse emittance, slice energy spread, and longitudinal distribution profile. This paper covers the current state of the design.

Footnotes:

Funding Agency:

This work is supported by Jefferson Science Associates, LLC under U.S. DOE Contract DE-AC05-06OR23177 and Brookhaven Science Associates, LLC, Contract DE-SC0012704.

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Coolers Designs and Proposals / 41

Stochastic Cooling Simulations on Transverse and Longitudinal Planes

Author: Vasileios Tsiantis[1]

Co-authors: Davide Gamba [1]; Christian Carli [1]; Daniel Sittard [1]; Wolfgang Höfle [1]

[1] *European Organization for Nuclear Research*

Stochastic cooling is a technique for reducing the phase space volume of particle beams in accelerators improving the experimental conditions for facilities like Antiproton Decelerator at CERN. We present a stochastic cooling simulation model, for transverse and longitudinal plane. This work stydies the cooling performance of particle beams under different scenarios, like different gains or number of particles, applying a feedback mechanism on the longitudinal plane called filter cooling. Some cases of emittance and momentum spread reduction are presented,as well as some interesting scenarios of unsuccesful cooling. This model gives insights of stochastic cooling systems and limitations that arise and aims to be integrated with XSUITE for further applications .

Footnotes:

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Advanced Cooling Applications / 42

Stochastic Cooling Enhanced Steady-State Microbunching

Author: Xiujie Deng[1]

[1] *Tsinghua University*

In this paper, we propose to combine two promising research topics in accelerator physics, i.e., optical stochastic cooling (OSC) and steady-state microbunching (SSMB). Basically we want to apply OSC in an SSMB storage ring to speed up the damping to enable or boost the formation of microbunching, for high-power short-wavelength coherent radiation generation. The presented work is expected to be useful for both OSC and SSMB.

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High-Energy Cooling Applications II / 43

Electron Cooler for High-Energy Hadrons Based on Energy Recovery Linac

Author: Dmitry Kayran[1]

Co-authors: Alexei Fedotov [1]; Sergei Seletskiy [1]

[1] *Brookhaven National Laboratory*

The Electron Ion Collider (EIC) performance will benefit from cooling of the stored ions at three collision energies. Such cooling must counteract the emittance growth driven by IBS and beam-beam effects. A non-magnetized bunched beam electron cooler is one of the possible approaches to cooling colliding ions. Such an electron cooler must provide electron bunches up to 150 MeV with high average current in the cooling section. Currently there are several options under consideration to satisfy the cooling requirements at the high energy at EIC. In this talk we discuss the electron bunch quality requirements, challenges and design aspects of such electron cooler based on ERL and multiple passes of electron bunches through the cooling section compatible with EIC requirements at all energies.

Footnotes:

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Work supported by Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the U.S. Department of Energy.

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Cooler Designs and Applications II / 44

Beam Dynamics Studies for Low-energy Electron Cooler for Electron Ion Collider

Author: Dmitry Kayran[1]

Co-authors: Alexei Fedotov [1]; Gang Wang [1]; Jorg Kewisch [1]; Sergei Seletskiy [1]; Yichao Jing [1]

[1] *Brookhaven National Laboratory*

A Low-energy Electron Cooler (LEC) system is presently under design at Brookhaven National Laboratory to cool protons at the Electron Ion Collider (EIC) injection energy. The accelerator for the LEC must provide a high current high-quality electron beam at kinetic energy of 12.5 MeV to the cooling section. In current accelerator design we use DC photo-gun followed by a set of RF cavities to achieve the required operation energy and bunch quality in the cooling section. Beam dynamics in the LEC is determined by strong space-charge effects. In this paper, we discuss the layout of the LEC and present results of beam dynamics simulations.

Footnotes:

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Work supported by Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the U.S. Department of Energy.

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Advanced Cooling R&D Session / 45

The Optical Stochastic Cooling program at Fermilab

Author: Jonathan Jarvis[1]

Co-authors: Abhishek Mondal [1]; Alexander Romanov [1]; James Santucci [1]; Jinhao Ruan [1]; Michael Wallbank [1]; Parker Landon [2]; Valeri Lebedev [3]

[1] *Fermi National Accelerator Laboratory*

[2] *Boston University*

[3] *Joint Institute for Nuclear Research*

Recently, Optical Stochastic Cooling (OSC) became the first demonstrated method for ultra-high-bandwidth stochastic cooling. The initial experiments at Fermilab's IOTA ring explored the essential physics of the method and demonstrated cooling, heating and manipulation of beams and single particles. Having been validated in practice, with continued development, OSC carries the potential for dramatic advances in the state-of-the-art performance and flexibility for beam cooling and control. The ongoing program at Fermilab is now focused on the development of an OSC system that includes high-gain optical amplification, which promises a two-order-of-magnitude increase in the strength of the OSC force. Here we review the progress and plans for the amplified OSC program. This includes detailed lattice designs and tracking simulations for the various experimental configurations, designs and status for the various hardware systems, and near-term operational plans and use cases.

Footnotes:

Funding Agency:

This manuscript has been authored by FermiForward Discovery Group, LLC under Contract No. 89243024CSC000002 with the U.S. Department of Energy, Office of Science, Office of High Energy Physics.

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Coolers Designs and Proposals / 47

Longitudinal Beam Stacking in Storage Ring using Pulsed Electron Cooling

Authors: He Zhao[1]; Lijun Mao[2]; Xiaodong Yang[1]

[1] *Institute of Modern Physics, Chinese Academy of Sciences*

[2] *Institute of Modern Physics*

Longitudinal ion beam stacking in a storage ring using a barrier rf system combined with beam cooling has been successfully demonstrated in several experiments. Based on the bunching effect observed in the pulsed electron beam cooling experiment at HIRFL-CSRm, we propose a new beam stacking scheme using only pulsed electron beam, in which the barrier voltage and cooling process can be achieved simultaneously. In this paper, we introduce this longitudinal stacking scheme along with the theory of beam dynamics and present a simple analytical model. The simulation demonstrates that this approach could be a useful beam stacking technique without the need for barrier bucket hardware. Moreover, the optimization and limitation of this stacking scheme are discussed, and the effect of the electron beam distribution on the barrier voltage is studied. This stacking method is expected to be a promising tool for accumulating RIBs in low- and medium-energy storage rings, such as the SRing of the HIAF project, where high-precision experiments require efficient accumulation techniques.

Footnotes:

Funding Agency:

National Natural Science Foundation of China and Chinese Academy of Sciences

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Laser Cooling Session / 48

Laser Cooling of Relativistic Ion Beams

Author: Michael Bussmann[1]

[1] *Helmholtz-Zentrum Dresden-Rossendorf*

This talk discusses fundamentals of ion beam cooling with continuous wave and pulsed laser systems at relativistic energies. It starts with reviewing key aspects of laser cooling of ion beams before discussing recent expeimental results from Germany and China. It then looks at the prospects of integrating permanent laser coolers into storage ring facilities such as SIS 100 at FAIR an the possibilities for studying beam dynamics, plasma physics, atomic physics of highly charged ions and fundamental physics with these beams.

Footnotes:

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Laser Cooling Facilities Session / 49

The SIS100 laser cooling facility at FAIR

Author: Danyal Winters[1]

Co-authors: Michael Bussmann [2]; Tamina Grunwitz [3]; Jens Gumm [3]; Volker Hannen [4]; Sebastian Klammes [1]; Benedikt Langfeld [3]; Ulrich Schramm [2]; Denise Schwarz [3]; Matthias Siebold [2]; Peter Spiller [1]; Thomas Stöhlker [1]; Ken Ueberholz [4]; Thomas Walther [3]

[1] *GSI Helmholtz Centre for Heavy Ion Research*

[2] *Helmholtz-Zentrum Dresden-Rossendorf*

[3] *Technical University of Darmstadt*

[4] *University of Münster*

The heavy-ion synchrotron SIS100 is (at) the heart of the Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany. It is designed to accelerate intense beams of heavy highly charged ions up to relativistic velocities and to deliver them to unique physics experiments, such as those planned by the APPA/SPARC collaboration. In order to cool these extreme ion beams, bunched beam laser cooling will be applied using a dedicated facility at the SIS100. We will use a novel 3-beam concept, where laser beams from three complementary laser systems (cw and pulsed) will be overlapped in space, time and energy to interact simultaneously with a very broad ion velocity range in order to maximize the cooling efficiency. We will present this project and give an update of its current status.

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Cooler Designs and Applications II / 50

Optics Design for a Storage Ring Based Electron Cooler for Cooling at High Energies

Author: Jorg Kewisch[1]

Co-authors: Alexei Fedotov [1]; Dmitry Kayran [1]; Jonathan Unger [2]; Sergei Seletskiy [1]; Yichao Jing [1]

[1] *Brookhaven National Laboratory*

[2] *Cornell University (CLASSE)*

The Ring Electron Cooler (REC) is an option to provide beam cooling for the EIC at high energies. Based on a storage ring this machine can provide the beam current necessary for cooling at higher energies. While the electrons cool the ions the radiation cooling of the electrons is enhanced using strong wiggler magnets. The ring has a race track shape where one 176 meter long straight section is used for ion cooling and the other includes the wigglers with a peak field of 2.4 Tesla. In our solution the sextupoles and octupoles necessary for chromaticity correction are also located in the wiggler section, where the dispersion function is optimized in the multipoles without increasing the emittances too much through radiation excitation and intra beam scattering. A constant dispersion in the cooling section allows redistributing cooling power from the longitudinal to the transverse direction. A dispersion-free section is inserted into the arcs for RF cavities and injection.

Footnotes:

Funding Agency:

Work supported by Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the U.S. Department of Energy.

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Cooling Technology / 51

BBU Thresholds and Digital Feedback Suppression for Frequency-Scaled BNL Cavities in the EIC Energy-Recovery Linac

Authors: Isurumali Neththikumara[1]; Kirsten Deitrick[1]; Nicholas Sereno[2]; Sadiq Setiniyaz[1]

[1] *Thomas Jefferson National Accelerator Facility*

[2] *Argonne National Laboratory*

The Electron–Ion Collider (EIC) achieves its design luminosity by cooling the ion beam with a high-current electron beam generated in an energy-recovery linac (ERL). The baseline ERL lattice employs a BNL five-cell cavity that is frequency-scaled to 197 MHz, 591 MHz, and 1.773 GHz, raising concerns about multibunch beam-breakup (BBU) instabilities. Threshold currents for each frequency option are established with two independent BBU tracking codes, providing cross-validated operating margins that guide cavity selection. To further increase the current limit, we incorporate a digital transverse feedback (FB) system that targets the dominant higher-order modes (HOMs). Simulations show the FB raises the BBU threshold by roughly an order of magnitude: power-spectral-density analysis of the beam centroid at the linac exit confirms strong suppression of the aliased HOM peak, although some spectral growth appears at secondary frequencies. This combined study quantifies baseline BBU limits, demonstrates effective active mitigation, and charts a practical path toward robust, high-current operation of the EIC ERL.

Footnotes:

Funding Agency:

This work was produced in part by Jefferson Science Associates, LLC under Contract No. AC05-06OR23177 with the U.S. Department of Energy.

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Coolers Designs and Proposals / 52

A Charge-Agnostic Design for 6D Muon Ionization Cooling

Author: Caroline Riggall[1]

[1] *University of Tennessee at Knoxville*

A muon collider presents a compelling path forward for high-energy physics, offering both energy reach and precision. The notable challenge in realizing the target luminosities for a muon collider is in the development of a sufficiently fast cooling scheme – one capable of several orders of magnitude in emittance reduction with minimal decay losses. Ionization cooling is presently considered the only scheme to fit this criterion. Traditional ionization cooling channels are characterized by a solenoid-based lattice for beam focusing and a low-Z absorbing material to facilitate emittance exchange. Dipole fields are used to generate dispersion such that higher-momentum muons pass through more absorbing material, enabling longitudinal cooling. The problem with this approach is the charge-specificity of the dispersion function, necessitating separate channels for μ^+ and μ^-. Here, the Helical FOFO Snake (HFOFO) is presented as an alternative approach to 6D cooling that agnostically treats both signs of muon, enabling a single cooling channel for both.

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High-Energy Cooling Applications I / 53

Electron Ion Collider Strong Hadron Cooling Design Summary

Author: Erdong Wang[1]

[1] *Brookhaven National Laboratory*

The Electron-Ion Collider (EIC) requires a high-energy cooler to maintain excellent beam quality and achieve high luminosity throughout long collision stores. To meet this requirement, the EIC project studied a novel approach known as Coherent Electron Cooling (CeC)—referred to as Strong Hadron Cooling (SHC)—which can provide rapid cooling rates at high energies. The SHC relies on an Energy Recovery Linac (ERL) to provide the intense, high-quality, and low-noise electron beam essential for the cooling process. This talk will overview and summarize the design progress of the Strong Hadron Cooler for the EIC. We will discuss key aspects of the project, including cooling physics, main parameters, the ERL design, risk mitigation strategies, and remaining challenges. Successful outcomes R&Ds could pave the way for a future proposal to implement SHC as an upgrade to the EIC, unlocking its full luminosity potential.

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54

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