15th International Conference on Heavy Ion Accelerator Technology

HIAT

2022 | Darmstadt

June 27 - July 1

GERMANY

Abstract Booklet

- Circular Accelerators and Storage Rings
- Radioactive Ion Beam Facilities
- Electrostatic Accelerators
- Applications
- Linacs
- New Concepts
- Accelerator Components
- Ion Sources, Traps and Charge Breeding

indico.gsi.de/e/HIAT2022

HFHF Helmholtz Forschungsakademie Hessen für FAIR

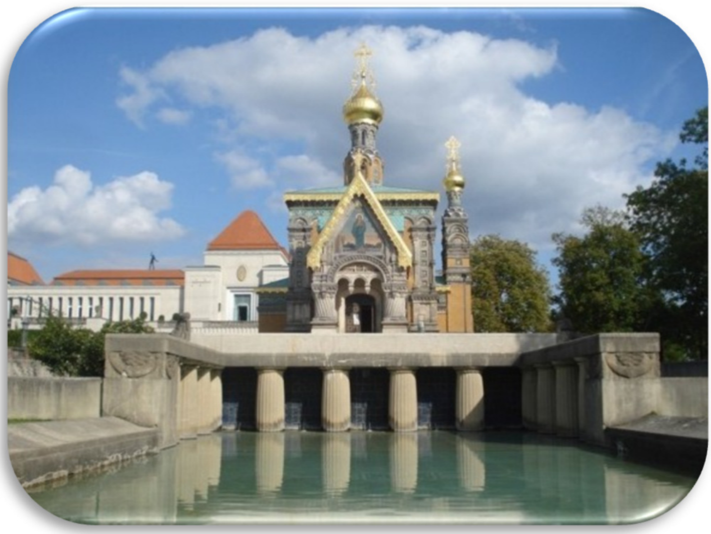
HIM HELMHOLTZ Helmholtz-Institut Mainz

GSI

FAIR

City of Darmstadt

The 15th International Conference on Heavy Ion Accelerator Technology welcomes you in the Rhine-Main Metropolitan Region, in the City of Darmstadt, Germany. Darmstadt, also dubbed the “City of Science”, is a major center of science institutes like GSI/FAIR. It is home to three universities and hosts the European Space Operation Centre (ESOC). It has also a rich cultural heritage. Most notably it was a centre of the Art Nouveau movement (“Jugendstil”) and is hence awarded a UNESCO world heritage site, the “Mathildenhöhe”.



About GSI

The GSI Helmholtzzentrum für Schwerionenforschung in Darmstadt operates a world-wide leading accelerator facility for research purposes. Shareholders are the German Federal Government with 90%, the State of Hesse with 8%, the State of Rhineland-Palatinate and the Free State of Thuringia with 1% each. They are represented in the GSI supervisory board by the Federal Ministry of Education and Research and the respective state ministries. GSI is a member of the Helmholtz Association, Germany's largest research organization.

About FAIR — Facility for Antiproton and Ion Research

At GSI, FAIR is currently being built, an international accelerator facility for the research with antiprotons and ions which is being developed and constructed in cooperation with international partners. It is one of the world's largest construction projects for international cutting-edge research. The FAIR project was initiated by the scientific community and researchers of GSI. The GSI accelerators will become part of the future FAIR facility and serve as the first acceleration stage.

For the realization of FAIR the FAIR GmbH, an international company under German law, was founded. The shareholders of FAIR come from nine countries: Finland, France, Germany, India, Poland, Romania, Russia, Slovenia, Sweden. The United Kingdom is associated. The Czech Republic is aspirant partner.

The FAIR GmbH has about 60 employees. The GSI GmbH is the German shareholder and also the main shareholder of the international FAIR GmbH. GSI is responsible for the development, production and testing of substantial components of the FAIR accelerator facility and the experiment setups. The efficient cooperation of FAIR and GSI is enabled by the joint organization of both GmbHs under one Management Board.

Conference Hotel

The conference takes place in the **“Welcome Hotel”** in the very center of Darmstadt and right beside it's most prominent park, the English style former royal garden “Herrngarten”.

The venue is easy to reach via a direct bus connection between the airport Frankfurt and Darmstadt, the so called “Airliner” or in general by public transport (local transport **rmv.de,** long distance transport **bahn.de).**

Dear colleague and participant of **HIAT 2022**

GSI/FAIR is honored to host the 15th International Conference on Heavy Ion Accelerator Technology in the Rhine-Main Metropolitan Region, in the City of Darmstadt, Germany. To allow for the original in person conference experience the 15th HIAT has been shifted by one year to 2022. It starts on Monday, 27 June 2022 and will last until Friday, 1 July, 2022.

HIAT 2022 is the 15th in a series of conferences, going back to 1973 in Daresbury and followed by Strasbourg (1977), Oak Ridge (1981), Buenos Aires (1985), Strasbourg-Heidelberg (1989), Legnaro (1992), Canberra (1995), Argonne (1998), Delhi (2002), Brookhaven (2005), Venice (2009), Chicago (2012), Yokohama (2015) and Lanzhou (2018).

HIAT is dedicated to the design, construction, development and operation of heavy-ion accelerators and their components. It focuses on the operational experience of existing facilities, achievements in heavy-ion accelerator physics and technology, progress on the implementation of new projects and infrastructure upgrades, and trends in the proposal, design and application of heavy ion accelerators as well as their main systems and components. Topics for the HIAT 2022 are:

- Circular Accelerators and Storage Rings
- Radioactive Ion Beam Facilities and other Facilities
- Electrostatic Accelerators
- Applications: Medical, Materials, Isotopes, Space and others
- Room Temperature and Superconducting Linacs
- Ion Source, Traps and Charge Breeding
- Accelerator Systems and Components
- New Concepts and Applications for Heavy Ion Acceleration

All sessions will be plenary and consist of invited and contributed talks. A poster session, a lab tour of the GSI/FAIR accelerator complex including the FAIR construction site, and an excursion will complete the program. Because of the still or unfortunately again difficult travel situation we also offer an option for remote participation. All together we have 64 contributions, 47 talks, 17 posters and presently 102 participants (13 using the remote option).

A number of industrial partners kindly support this conference. You can meet them on Monday and Tuesday on the conference site and find information about them also in this book of abstracts. Their sponsorship enabled us to support 9 students and 2 post-docs to attend the conference.

On behalf of the local organizing committee I would like to welcome you to Darmstadt after a long time without proper conferences and workshops finally in person. The schedule provides ample time for the missed experience of lively discussions also on topics that only fit coffee breaks and excursions. The lab visit (a bus tour of the FAIR construction site) and excursion (a boat trip on the river rhine including the conference dinner) are combined with an open session at GSI/FAIR in the morning of the conference Wednesday.

I am looking forward to an inspiring and interesting conference HIAT2022!

Frank Herfurth

Chair HIAT2022

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Sponsoring

Additionally to the support by the hosting institute, GSI Helmholtz Centre for heavy ion research mbH, two neighboring institutes, the Helmholtz Institute Mainz and the Helmholtz Research Academy Hesse for FAIR, support the HIAT 2022 conference.

GSI

www.gsi.de

HIM HELMHOLTZ
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www.hi-mainz.de

HFHF
Helmholtz Forschungsakademie Hessen für FAIR

hfhf-hessen.de

HIAT 2022 also thankfully reports the support by a number of industrial partners. Those partners will present their products during an industrial exhibition on **Monday** and **Tuesday** within the conference week. All conference participants have hence the opportunity and are welcome to meet our industrial partners in person.

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Table of Abstracts

Contents

MO1 — Monday Session 1

MO1N0 09:00 10

Welcome to HIAT 2022

F. Herfurth *(GSI)*

Welcome to HIAT 2022

MO1I1 09:10 30

Laser-Ion Acceleration in Plasmas

J. Schreiber *(LMU)*

Chirped pulse amplification (CPA) laser systems such as the Advanced Titanium-Sapphire Laser (ATLAS) operated in the Centre for Advanced Laser Applications (CALA) at the Ludwig-Maximilians-University (LMU) Munich can now provide laser pulses with Petawatt peak power and ~30 fs duration. When tightly focussed onto a target, typically a (sub-)micrometer thin foil, electrons are driven relativistically and seperated from ions, so that they are dragged along. The rectified electric fields that both generate high charge states as well as accelerate ions are of order of the laser fields, ~1 to 100 MV/µm. I will review the physical processes at play and present the characteristics of ion sources, in particular the energy distributions that are accessible with current technology. The fact that ions are energized by ultrashort laser pulses results in a number of intriguing and novel applications, for example time resolved investigation of processes that follow energy deposition in water. I will also report on recent observations of acceleration of gold ions to MeV/u kinetic energy. The observed charge state and energy distributions challenge physical models and inspire nonlinear nuclear physics approaches.

MO1I2 09:40 30

Superconducting Magnets Challenges for the Future

L. Rossi *(INFN/LASA)*

Superconducting (SC) magnets has accompanied the development of accelerators in the last 50 years. Starting from the pioneering work for the SC cyclotron in MSU, Chalk River and Milano, to the large FAIR complex, the progress of SC magnets has accompanied the increase in energy and intensity of the accelerators for heavy ions, too. SC magnets are now used for hadron therapy with heavy ions, with the installation and operation of the SC gantry in the carbon therapy center at HIMAC in Japan. The challenges for future SC magnet expand over three frontiers: I) the high field frontier, to enable higher beam energies; II) the fast-pulsing operation frontier, to enable high intensity beams, with high repetition rate synchrotrons; III) medical application frontier, noticeably in hadron therapy, where simple, reliable, medium field SC magnets with affordable cost can become of common use, expanding the utilization of heavy ion therapy.

27 Jun – Mon

MO1C3
10:10 20

High Voltage Upgrade of the 14UD Tandem Accelerator

C. Notthoff, *S.T. Battisson, A. Cooper, J.K. Heighway, D.J. Hinde, C. Kafer, P. Linardakis, N.R. Lobanov, T. Tempra, B. Tranter, R. Tranter, T.B. Tunningley, T. Kitchen (Research School of Physics and Engineering, Australian National University) R.A. Bosch (UW-Madison/SRC) J.E. Raatz (NEC)*

The 14UD at the Australian National University's Heavy Ion Accelerator Facility (HIAF) operated at a maximum voltage of 15.5 MV after the installation of tubes with a compressed geometry in the 1990s. In recent years, the performance of the accelerator has shown a gradual decline to a maximum operation voltage of ~14.5 MV. There are some fundamental factors that limit the high voltage performance, such as SF6 gas pressure, field enhancement due to triple junctions and total voltage effect. In 2019 ANU initiated the feasibility study of available options to upgrade the entire population of supporting posts, acceleration tubes and grading resistors. In this paper we will discuss the preferred technologies and strategies for successful implementation of this development. The chosen design is based on NEC tubes with magnetic electron suppression and minimized steering of ion beam. The new grading resistors mounting options and improved voltage distribution along accelerator column timeline will be discussed.

MO2 — Monday Session 2

MO2I1 11:00 30

ISOLDE Isotope Production (LE, Post-Accel), for Physics, Material and Life Sciences (MEDICIS Inclusive), Facility Upgrades

M. Kowalska *(CERN)*

The speaker did not provide an abstract.

MO2I2 11:30 30

Radioactive Ion Beams at TRIUMF, ISAC and ARIEL: Status and Perspectives

F. Ames *(TRIUMF)*

TRIUMF's ISAC facility delivered for more than two decades radioactive ion beams to experiments. The isotopes are produced by bombarding solid targets with a beam of 500 MeV protons. Singly charged ions up to 60 keV are extracted, mass selected and distributed to experiments. For experiments requiring higher energy, they are accelerated up to 15 MeV/u by a heavy ion linac consisting of an RFQ, a room temperature drift tube structure and a superconducting linac. Ions with a mass > 30amu are charge state bred with an ECR ion source. A new facility under construction (ARIEL) aims to dripple the amount of beam time available to users. It combines two target stations, a high-resolution mass separator and an EBIS charge breeder. One target station will produce the isotopes from up to 100 kW electrons at 30 MeV and photo fission, while the other one with an additional proton beam from the TRIUMF cyclotron. Results from the existing ISAC facility will be presented. Plans for improvements to ISAC operation and the status of the ARIEL set up will be discussed together with an operational model to run simultaneously all three target stations.

MO2C3 12:00 20

Status and Perspective of ECR Based Charge Breeders

J. Angot*, M.A. Baylac, M. Migliore, T. Thuillier (LPSC)*

Since their invention in the late 1990s, ECR based Charge Breeders have been used in several Isotope Separation On Line facilities to study radioactive ions. The goal of these instruments is to increase the charge state of the ion beam before their post acceleration by cyclotrons or LINAC based particle accelerators. As a key part of the ISOL method, extensive R&D programs have been conducted by different laboratories to increase the efficiency and reduce the multi-ionization duration of the charge breeding process. Using the injected beam as a diagnostic tool, such a source is also a powerful device to probe and to investigate ECR plasmas. ECR Charge Breeders application to facilities with low radioactive ion beam yield has been limited by the N+ beam contamination with unwanted chemical components ionized in the ECR plasma. A special R&D effort is undergone to tackle this limitation and to optimize the performances of this robust and reliable instrument. After an overview of ECR Charge Breeders worldwide and of the latest developments, the R&D perspective will be discussed.

MO3 — Monday Session 3

MO3I1
14:00 30

Developments towards a Compact Carbon Ion Linac for Cancer Therapy (ACCIL)

B. Mustapha, *A. Nassiri, J.A. Nolen, J.R. Noonan (ANL) R.B. Agustsson, S. Boucher, S.V. Kutsaev, A.Yu. Smirnov (RadiaBeam)*

Hadron therapy offers improved localization of the dose to the tumor and much improved sparing of healthy tissues, compared to traditional X-ray therapy. Combined proton/carbon therapy can achieve the most precise dose confinement to the tumor. Moreover, recent studies indicated that adding FLASH capability to such system may provide significant breakthrough in cancer treatment. The Advanced Compact Carbon Ion Linac (ACCIL) is a conceptual design for a compact ion linac based on high-gradient accelerating structures operating in the S-band frequency range. Thanks to this innovation, the footprint of this accelerator is only 45 m, while its capabilities are well beyond the current state of the art for hadron therapy machines and include: operation up to 1000 pulses per second, pulse to pulse energy variation to treat moving tumors in layer-by-layer regime. ACCIL is capable of accelerating all ions with mass-to-charge ratio A/q ~ 2 to a full energy of 450 MeV/u, and that includes protons, helium, carbon, oxygen and neon. With very short beam pulses of ~ 1 's and high instantaneous dose delivery, ACCIL is capable of delivering FLASH-like doses (>100 Gy/sec) for most ion species. In close collaboration between Argonne and Radiabeam, we have developed different design options and prototypes of the high-gradient structures needed for ACCIL. Following an overview of the ACCIL design and its capabilities, the most recent results from the high-gradient structure R&D and future plans will be presented and discussed.

MO3C2
14:30 20

Establishment of the New Particle Therapy Research Center (PARTREC) at UMCG Groningen

A. Gerbershagen, *L. Barazzuol, S. Both, S. Brandenburg, R.P. Coppes, P.G. Dendooven, B.N. Jones, J.M. Schippers, E.R. Van Der Graaf, P. Van Luijk, M.-J. van Goethem (PARTREC)*

After 25 years of successful research in the nuclear and radiation physics domain, the KVI-CART research center in Groningen is upgraded and reestablished as the PARticle Therapy REsearch Center (PARTREC). Using the superconducting cyclotron AGOR and being embedded within the University Medical Center Groningen, it operates in close collaboration with the Groningen Proton Therapy Center. PARTREC uniquely combines radiation physics, medical physics, biology and radiotherapy research with an R&D program to improve hadron therapy technology and advanced radiation therapy for cancer. A number of further upgrades, scheduled for completion in 2023, will establish a wide range of irradiation modalities, such as pencil beam scanning, shoot-through with high energy protons and SOBP for protons, helium and carbon ions. Delivery of spatial fractionation (GRID) and dose rates over 300 Gy/s (FLASH) are envisioned. In addition, PARTREC delivers a variety of ion beams and infrastructure for radiation hardness experiments conducted by scientific and commercial communities, and nuclear science research in collaboration with the Faculty of Science and Engineering of the University of Groningen.

MO3I3
14:50 30

Heavy Ion Stripping

***P. Gerhard**, M.T. Maier (GSI)*

Ion stripping is primarily an essential technique for heavy ion accelerators in order to reach higher beam energies within reasonable size and budget limits. Due to the nature of the stripping process, the resulting ion beam contains ions of different charge states. Therefore, high beam loss is typically associated, making the net stripping efficiency one of the decisive elements of the overall performance of an accelerator or facility. Several technical implementations of strippers have been and are still being developed in order to obtain optimal stripping for different ions and beam energies by employing different kinds of stripping targets, namely gaseous, solid and more recently fluid materials. High beam intensities resulting in prohibitive energy deposition and target destruction are challenging. Optimizing a stripper may potentially increase the overall performance by a large factor with less effort than other actions. This gave rise to the pulsed gas stripper project at the GSI UNILAC. This talk will give an overview of different strippers at GSI and beyond. The second part will give a detailed report on the introduction of hydrogen at the GSI gas stripper.

27-Jun-22 16:00 – 17:30 Plenary Session

MO4 — Monday Session 4

MO4I1
15:50 30

High Beam Power Operations at RIKEN RIBF: Technical Developments, Challenges and Resolutions

O. Kamigaito, *T. Dantsuka, H. Fujii, M. Fujimaki, N. Fukunishi, H. Hasebe, Y. Higurashi, H. Imao, M. Kidera, M. Komiyama, K. Kumagai, T. Maie, T. Nagatomo, T. Nakagawa, M. Nakamura, T. Nishi, J. Ohnishi, H. Okuno, K. Ozeki, N. Sakamoto, K. Suda, A. Uchiyama, T. Watanabe, Y. Watanabe, K. Yamada (RIKEN Nishina Center) T. Adachi, Y.M. Miyake (RIKEN)*

The Radioactive Isotope Beam Factory (RIBF) of RIKEN is a cyclotron-based heavy ion accelerator facility, which accelerates heavy ions up to uranium to 345 MeV/u using an accelerator complex with a K2600-MeV Superconducting Ring Cyclotron (SRC) in the last stage to produce rare isotope beams in an in-flight technique. The first beam was obtained in 2006 and the beam service to the users was started in the following year. In the 15 years of effort since then, the intensity and stability of the heavy ion beams have been dramatically improved. For example, the uranium beam extracted from the SRC reached 117 pnA, exceeding the facility goal of 100 pnA set in 2011. The beam power is 9.6 kW. ^{70}Zn beams have reached an intensity of 788 pnA and a beam power of 19.0 kW. The availability of the accelerator has also exceeded 90 %. Various scientific results on unstable nuclei have been produced by these beams. The core experimental instrumentations such as the Rare RI Ring are now in operation, and further results are expected in the future. This paper introduces the various technological developments that have been made since the start of RIBF acceleration and discusses future directions.

MO4I2
16:20 30

Liquid Lithium Charge Stripping Commissioning with Heavy Ion Beams

T. Kanemura, *R. Madendorp, F. Marti, T. Maruta, Y. Momozaki, P.N. Ostroumov, A.S. Plastun, J. Wei, Q. Zhao (FRIB) M.J. LaVere (MSU)*

The Facility for Rare Isotope Beams (FRIB) at Michigan State University is a 400 kW heavy ion linear accelerator. Heavy ion accelerators normally include a charge stripper to remove electrons from the beams to increase the charge state of the beams thus to increase the energy gain. Thin carbon foils have been the traditional charge strippers but are limited in power density by the damage they suffer (sublimation and radiation damage) and consequently short lifetimes. Because of the high beam power, FRIB had decided to use a liquid lithium charge stripper (LLCS), a self-replenishing media that is free from radiation damage. FRIB recently commissioned a LLCS with heavy ion beams (^{36}Ar, ^{124}Xe and ^{238}U beams at energies of 17-20 MeV/u). Since there had been no experimental data available of charge stripping characteristics of liquid lithium, this was the first demonstration of charge stripping by a LLCS. The beams were successfully stripped by the LLCS with slightly lower charge states than the carbon foils of the same mass thickness. FRIB has become the world's first accelerator that includes the LLCS.

MO4C3
17:10 20

Development, Fabrication and Testing of the RF-Kicker for the Acculinna-2 Fragment Separator

W. Beeckman, *F. Forest, O. Tasset-Maye, E.J. Voisin (SIGMAPHI S.A.) A. Bechtold (NTG Neue Technologien GmbH & Co KG) A.S. Fomichev, A.V. Gorshkov, S.A. Krupko, G.M. Ter-Akopian (JINR/FLNR)*

The Acculinna-2 radioactive beam separator was designed and built between 2012 and 2014, then installed and tested by Sigmaphi in 2015 and in full operation since 2016 at the Flerov laboratory of JINR in Dubna. In order to achieve efficient separation of neutron-deficient species, an RF kicker was foreseen since the beginning of the project but was put on hold for many years. In 2016 Sigmaphi got a contract to study, build, install and test an RF kicker with a variable frequency ranging between 15 and 21 MHz and capable of producing 15 kV/cm transverse electric fields in a 10 cm gap over a 1m long distance.

The presentation first recalls the rationale of an RF-kicker to separate neutron-deficient species. It then goes through the different steps of the study, initial choice of the cavity structure, first dimensioning from analytical formulas, finite elements computations and tuning methods envisioned, down to a final preliminary design.

A 1/10 scaled mock-up of this final shape was built and tested as a check before building the full-size cavity. The NTG company was then contracted to perform, in a joint collaboration with Sigmaphi, the final study, detailed design, construction and factory testing of the real cavity. The presentation highlights the fabrication and tests of both mock-up and real size cavities through a series of pictures.

The complete RF-kicker, with its power supply, control and pumping systems was installed on the Acculinna-2 beamline in June 2019. Because the U400M cyclotron was due to shut down by mid-2020, the Acculinna-2 team decided to use the separator to accumulate as much data as possible, to be processed during the 2 years closing time. A 1-week time window for kicker testing was only available in February 2020, a short but sufficient time lapse to successfully drive the cavity at full power and test it over a wide frequency range. Unfortunately, because of cyclotron closure, no beam tests have been performed so far. The latest available results are discussed in the presentation.

TU1 — Tuesday Session 1

TU1I1
09:00 30

3D Printing (Additive Manufacturing) Applied to Accelerator Components

T. Torims *(Riga Technical University)*

The speaker did not provide an abstract.

TU1C2
09:30 20

Surface Treatment Procedures to Mitigate Ion-Induced Desorption in Heavy Ion Accelerators

V. Velthaus*, M. Bender, C. Trautmann (GSI)*

Ion-induced desorption is a serious limitation for stable operation of high beam intensities in heavy ion synchrotrons. Next generation heavy ion accelerators like FAIR or SPIRAL2 are designed for intensities that are orders of magnitude higher than the intensity of existing machines. Hence, ion-induced desorption becomes a big challenge. To better understand and control the influence of material and surface factors, desorption measurements with swift heavy ions (Ca and Au at 4.8 MeV/u) were conducted with focus on oxygen-free copper and tungsten samples. The surfaces were treated by different combinations of milling, lapping, polishing, etching and sputtering. Some of the samples were coated by carbon, titanium nitride or TiZrV. For all tested samples desorption yields (number of released molecules per impacting ion) for H_2, H_2O, CO, CO_2, O_2 and Ar will be presented. For copper, surface cleaning by sputtering with 5 keV argon ions reduces the desorption yield significantly. Another promising method to reduce ion-induced desorption is thermal annealing at 400^{o}C for about 4 h under ultra-high vacuum conditions. Suitable annealing and cleaning parameters will be presented.

TU1C3
09:50 20

Turbopumps: Lowest Vibration and Highest Uptime Made with Laser Balancing Technology

A. Hannweg *(Pfeiffer Vacuum GmbH)*

The balance quality of a rotor has an influence on its uptime and vibration. With a rotor speed of up to 1500 Hz, it is particularly large for turbopumps, which therefore are sensitive to the smallest mass unbalances. A certain unbalance cannot be completely avoided, which will always lead to a rotating radial force and thus vibrations. Reducing the unbalance is a necessity for the safe and reliable operation of turbopumps and has a positive impact on numerous vibration sensitive applications. Furthermore, the reduction of the radial forces extends the lifetime of the bearing that supports the rotor, which lowers the maintenance frequency. In the past, the best balance was achieved by adding additional mass (balancing screws), or by removing mass with machining processes. The latest and currently most efficient method is Laser Balancing, where the unbalance compensation is achieved by removing rotor material in the form of segments with the technique of laser ablation. This innovative technology was developed and patented by Pfeiffer Vacuum.

TU1C4
10:10 20

A 3D Printed IH-Type Linac Structure - Proof-of-Concept for Additive Manufacturing of Linac RF Cavities

H. Hähnel, *U. Ratzinger (IAP)*

Additive manufacturing ("AM" or "3D printing") has become a powerful tool for rapid prototyping and manufacturing of complex geometries. A 433 MHz IH-DTL cavity has been constructed to act as a proof of concept for additive manufacturing (AM or 3D printing) of linac components. In this case, the internal drift tube structure has been produced from 1.4404 stainless steel using AM. We present the concept of the cavity as well as first results of vacuum testing and materials testing. Vacuum levels sufficient for linac operation have been reached with the AM linac structure.

TU2 — Tuesday Session 2

TU2I1 11:00 30

Preparation for the RAON SCL Beam Commissioning JANG

J.-H. Jang *(IBS)*

The speaker did not provide an abstract.

TU2I2 11:30 30

Development and Commissioning of the K500 Superconducting Heavy Ion Cyclotron

S. Som, *A. Bandyopadhyay, S. Bandyopadhyay, S. Bhattacharya, P. Bhattacharyya, T. Bhattacharyya, U. Bhunia, N. Chaddha, J. Debnath, M.K. Dey, A. Dutta Gupta, S. Ghosh, A. Mandal, P.Y. Nabhiraj, C. Nandi, Z.A. Naser, S. Pal, S. Pal, U. Panda, J. Pradhan, A. Roy, S. Saha, S. Seth, S.K. Thakur (VECC)*

The K500 Superconducting Cyclotron (SCC) has been developed indigenously and commissioned at VECC. The three-phase Radio-Frequency (RF) system of SCC, consists of three half-wave cavities placed vertically 120 deg. apart. Each half-wave cavity has two quarter-wave cylindrical cavities tied together at the centre and symmetrically placed about median plane of the cyclotron. Each quarter-wave cavity is made up of a short circuited non-uniform coaxial transmission line (called "dee-stem") terminated by accelerating electrode (called "Dee"). The SCC, operating in the range 9 to 27 MHz, has amplitude and phase stability within 100 ppm and 0.1 deg. respectively. The overview of all the subsystems of the cyclotron along with low-level RF (LLRF), high and low power RF amplifiers, cavity analysis, absolute Dee voltage measurement using X-ray method, amplitude and phase control loops will be presented in the talk. The commissioning of the cyclotron with first harmonic Nitrogen^{4+} beam extracted at 252 MeV, while operating at 14 MHz RF frequency, along with the correction of first harmonic magnetic field error by repositioning the cryostat within 120 micron accuracy, will be discussed briefly.

TU2C3 12:00 20

The status of Proton Testbeam at KAHVELab

S. Esen, *A. Hamparsunoglu, O. Kocer, S. Oz (Istanbul University) S. Aciksoz, E. Celebi, E. Elibollar, S. Ogur, E.V. Ozcan (Bogazici University) A. Adiguzel, S. Ogur, S. Ogur (CERN) A. Caglar, D. Halis, T.B. Ilhan (YTU) E. Celebi (IBU) H. Cetinkaya (Dumlupinar University, Faculty of Science and Arts) U. Kaya (Istinye University, Institute of Sciences) A. Kilicgedik (Marmara University) S. Ogur (Université Paris-Saclay, CNRS/IN2P3, IJCLab) G. Türemen (Ankara University, Faculty of Sciences) G. Türemen (Turkish Atomic Energy Authority) G. Türemen (TAEK) G. Unel (UCI)*

This presentation reports on the Proton Testbeam at KAHVElab (PTAK) at Bogazici University in Istanbul, Turkey. PTAK consists of two different Microwave Discharge Ion Sources (IS), a Low Energy Beam Transfer (LEBT) section, and an RFQ accelerator. LEBT consist of two solenoids, two steerer magnet, and a beam Diagnostic Box including a Faraday cup and a pepper pot plate for measuring incoming beam current, and emittance measurement. The RFQ is a one-meter long, two module, four-vane

cavity, designed to operate at 800MHz. Until now, the IS and the LEBT are installed and their commissioning is ongoing. An RFQ test module is constructed and is being subjected to electromagnetic and vacuum tests. The PTAK construction is scheduled to achieve a 2 MeV proton beam on target by the end of 2023.

TU2C4 12:20 20

Beam Tuning Automation Activities at TRIUMF

***S. Kiy**, F. Ames, A. Andres, R.A. Baartman, H. Bagri, K. Ezawa, W. Fedorko, P.M. Jung, O.K. Kester, K.E. Lucow, J. Nasser, T. Planche, S.D. Rädel, B.E. Schultz, O. Shelbaya, B. Stringer, D.C. Thomson, D.Y. Wang, K.C. Wu (TRIUMF) J.A. Adegun (UVIC)*

The particle accelerator complex at TRIUMF provides beams for secondary particle production including rare isotopes. The post acceleration of rare isotope ions demands frequent changes of beam properties like energy and changes of the ion species in terms of isotope and charge state. To facilitate these changes to beam properties and species, a High Level Applications (HLA) framework has been developed that provides the essential elements necessary for app development: access to sophisticated envelope simulations and any necessary beamline data, integration with the control system, version control, deployment and issue tracking, and training materials. With this framework, one can automate collection of beam data and subsequently pull that data into a model which then outputs the necessary adjustments to beam optics. Tuning based on this method is model coupled accelerator tuning (MCAT) and includes pursuits like the training of machine learning (ML) agents to optimize corrections benders. A summary of the framework will be provided followed by a description of the different applications of the MCAT method - both those currently being pursued, and those envisioned for the future.

TU3 — Tuesday Session 3

TU3I1
14:00 30

Deceleration of Highly Charged Heavy Ion Beams

***M. Steck**, R. Hess, R. Joseph, S.A. Litvinov, B. Lorentz, U. Popp (GSI)*

Deceleration of highly charged ions is an important mode for the operation of the ESR storage ring at GSI. Low energy beams of highly charged heavy ions are either required for internal experiments or can be transferred after fast extraction to the low energy storage ring CRYRING@ESR or to the HITRAP facility, in both facilities further deceleration is possible. In order to have high stripping efficiency and sufficient production rate for the highest charge states and rare isotope beams several hundred MeV/u of beam energy are required. After production of the highly charged ions in a stripper foil or rare isotope beams in a thick target the highly charged ions are injected into the ESR at an energy of typically 400 MeV/u. Consecutively the ions can be decelerated to a variable final energy with a minimum energy of 3 MeV/u. The deceleration process is supported by either stochastic cooling at the injection energy or electron cooling available over the whole energy range. The basic challenges and features of beam deceleration in the storage ring will be presented.

TU3I2
14:30 30

Beam Instrumentation, Challenging Tools for Demanding Projects — a Snapshot from the French Assigned Network

***F. Poirier**, T. Durand, C. Koumeir (Cyclotron ARRONAX) T. Adam, E. Bouquerel, C. Maazouzi, F.R. Osswald (IPHC) B. Cheymol, D. Dauvergne, M.-L. Gallin-Martel, R. Molle, C. Peaucelle (LPSC) L. Daudin, A.A. Husson, B. Lachacinski, J. Michaud (LP2I) N. Delerue, H. Guler (Université Paris-Saclay, CNRS/IN2P3, IJCLab) C. Jamet (GANIL) C. Thiebaux, M. Verderi (LLR)*

Particle accelerators are thrusting the exploration of beam production towards several demanding territories, that is beam high intensity, high energy, short time and geometry precision or small size. Accelerators have thus more and more stringent characteristics that need to be measured. Beam diagnostics accompany these trends with a diversity of capacities and technologies that can encompass compactness, radiation hardness, low beam perturbation, or fast response and have a crucial role in the validation of the various operation phases. Their developments also call for specialized knowledge, expertise and technical resources. A snapshot from the French CNRS/IN2P3 beam instrumentation network is proposed. It aims to promote exchanges between the experts and facilitate the realization of project within the field. The network and several beam diagnostic technologies will be exposed. It includes developments of system with low beam interaction characteristics such as PEPITES, fast response detector such as the diamond-based by DIAMMONI, highly dedicated BPM for GANIL-SPIRAL2, emittance-meters which deals with high intensity beams and development for MYRRHA, SPIRAL2-DESIR and NEWGAIN.

TU3C3
15:00 20

Preparation of Low-Energy Heavy Ion Beams in a Compact Linear Accelerator/Decelerator

***Z. Andelkovic**, S. Fedotova, W. Geithner, P. Gerhard, F. Herfurth, I. Kraus, M.T. Maier, A. Reiter, G. Vorobyev (GSI)*

High precision tests of fundamental theories can often unfold their full potential only by using highly charged ions (HCI) at very low energies. Although in light of the envisaged energies at FAIR, experiments in the keV to MeV range may sound like backpedaling, these two techniques are in fact complementary, since the production of heavy HCI is virtually impossible without prior acceleration and electron stripping. However, subsequent preparation, transport, storage and detection of low-energy HCI bring new, surprising sets of problems and limitations. The talk will give an overview of the CRYRING@ESR local injector and the HITRAP linear decelerator. These two facilities consist out of one or two accelerator stages, with a total length of around 10 meters, making them "compact" in comparison to other GSI accelerators. We will present their main design parameters, the achieved ion numbers, challenges of beam detection, as well as some special features such as multi-turn injection and single-shot energy analyzers. The presentation will conclude with selected experimental achievements and will also give an outlook of the planned applications of low-energy ions at the FAIR facility.

TUP — Poster Session

TUP02 **SPIRAL2 facility evolution with the S3, DESIR and NEWGAIN Projects**

P. Anger, *M.H. Moscatello, H. Savajols, F. Varenne (GANIL)*

The SPIRAL2 Facility at GANIL is currently based on the operation of a superconducting ion CW LINAC (up to 5 mA - 40 MeV deuteron beams and up to 1 mA - 14.5 MeV/u heavy ion beams) with an experimental area called NFS for Neutrons For Science. Three new projects are under development: -The Super Separator Spectrometer facility (S3) designed to extend the capability of GANIL to perform experiments with extremely low cross sections, taking advantage of the very high intensity stable beams of the SPIRAL2 LINAC. S3 is in the installation and test phases and the commissioning is planned in the near future. -The Radioactive Ion Decay, Excitation and Storage facility (DESIR) is a low-energy beam facility at GANIL-SPIRAL2 to study the properties of exotic nuclei in unexplored regions of the nuclide chart. DESIR detailed design study is completed and the building construction phase will start soon. -The New GAnil Injector Facility (NEWGAIN) is a new injector, consisting of a superconducting ion source and an RFQ (A/q = 7), for the SPIRAL2 LINAC. It will enable GANIL to provide ion beams of worldwide highest intensities (from proton to uranium). NEWGAIN is under detailed study. This contribution will describe the status of these three projects to exploit the full potential of the SPIRAL2 LINAC accelerator and to strengthen the GANIL scientific program.

TUP03 **Bunch Merging and Compression: Recent Progress with RF and LLRF Systems for FAIR**

D.E.M. Lens, *R. Balß, H. Klingbeil, U. Laier, J.S. Schmidt, K.G. Thomin, T. Winnefeld, B. Zipfel (GSI) H. Klingbeil (TEMF, TU Darmstadt)*

Besides the realization of several new RF systems for the new heavy-ion synchrotron SIS100 and the storage rings CR and HESR, the FAIR project also includes an upgrade of the RF systems of the existing accelerator rings such as SIS18. The SIS18 RF systems currently comprise two ferrite cavities, three broadband magnetic-alloy cavities and one bunch-compressor cavity. In addition, the LLRF system has been continuously upgraded over the past years towards the planned topology that will be implemented for all FAIR ring accelerators. One of the challenges for the SIS18 RF systems is the large RF frequency span between 400 kHz and 5.4 MHz. Although the SIS18 upgrade is still under progress, a major part of the functionality has already been successfully tested with beam in machine development experiments (MDE). This includes multi-harmonic operation such as dual-harmonic acceleration and further beam gymnastics manipulations such as bunch merging and bunch compression. Many of these features are already used in standard operation. In this contribution, the current status is illustrated and recent MDE results are presented that demonstrate the capabilities of the RF systems for FAIR.

TUP04 **New Method for Overcoming Dipole Effects of 4-Rod RFQs**

S. Wunderlich, *C. Zhang (GSI)*

A new design of a 4-rod RFQ has been developed and simulated. In contrast to conventional designs, it uses asymmetrical stem geometry in the vertical-longitudinal plane. The effect on dipole fields for different geometrical parameters were examined and will be discussed.

TUP05 **Prototype Room Temperature Quadrupole Chamber with Cryogenic Surfaces**

S. Aumüller, *L.H.J. Bozyk, P.J. Spiller (GSI) K. Blaum (MPI-K)*

The FAIR complex at the GSI Helmholtzzentrum will generate heavy ion beams of ultimate intensities. As low charge states have to be used the probability for charge exchange in collisions with residual gas particles of such ions is much higher than for higher charge states. In the last years several measures have lowered the residual gas density to extreme high vacuum conditions, for example 55% of the circumference of SIS18 have already been coated with NEG, which provides high and distributed pumping speed. Nevertheless, this coating does not pump Nobel and Nobel-like components, which have very high ionization cross sections. A cryogenic environment at i.e. at 50-80K, provides a high pumping speed for all heavy residual gas particles, the only typical residual gas particle that cannot be pumped at this temperature is Hydrogen. With an additional NEG coating in these areas the pumping will be optimized for all residual gas particles. The installation of cryogenic surfaces in the existing room temperature synchrotron SIS18 at GSI has been investigated. Measurements on a prototype chamber and simulations of SIS18 with cryogenic surfaces based on these measurements are presented.

TUP06 **Cryogenic Surfaces in a Room Temperature SIS18 Ion Catcher**

L.H.J. Bozyk, *S. Aumüller, P.J. Spiller (GSI)*

For FAIR operation, the existing heavy ion synchrotron SIS18 at GSI will be used as booster for the future SIS100. In order to reach the intensity goals, low charge state heavy ions will be used. Unfortunately, such ions have very high ionization cross sections in collisions with residual gas molecules, yielding in beam loss and a subsequent pressure rise via ion impact stimulated gas desorption. To reduce the desorption yield, room temperature ion catcher have been installed, which provide low desorption surfaces. Simulations including cryogenic surfaces show, that their high sticking probability prevents the vacuum system from pressure built-ups during operation. Such, the operation with heavy ion beams can be stabilized at higher heavy ion intensities, than solely with room temperature surfaces. A prototype ion catcher containing cryogenic surfaces has been developed and built. The surfaces are cooled by a commercial cold head, which easily allows this system being integrated into the room temperature synchrotron. The development and first laboratory tests including fast pressure measurements of this system will be presented.

TUP07 **Efficient Heavy Ion Acceleration with High Brilliance**

C. Zhang *(GSI) H. Podlech (IAP)*

For accelerating high current heavy ion beams, space charge effects are most pronounced at the low energy end. It is often challenging to realize an efficient and brilliant accelerator dominated by space charge effects. Here "efficient" means an as short as possible accelerating structure with minimum RF power consumption, while "brilliant" means high beam transmission and low emittance growth. In this paper, a promising solution is presented.

TUP08 **RF Chopper for Prebunched Radioactive Ion Beams**

A.J. Gonzalez*, A.S. Plastun (FRIB)*

An RF chopper system is being designed for the Re-Accelerator (ReA) linac at the Facility for Rare Isotope Beams (FRIB) at Michigan State University (MSU). The chopper system is designed to clean out satellite bunches and produce a 16.1 MHz bunch structure, which allows for time-of-flight separation of the isotopes. The chopper system's location in the beamline is between the ReA3 and ReA6 cryomodules. In ReA, the beam can be prebunched at the frequency of 16.6 MHz and accelerated in a 80.5 MHz RFQ, producing four satellite bunches for every one high-intensity bunch. The chopper system includes a 64.4 MHz RF deflector, which deflects every bunch to spatially separate high-intensity and satellite bunches. The beam trajectory is biased by a constant magnetic field to ensure the high-intensity bunches do not experience any total deflection. The kicked bunches are low in intensity and will be sent to a beam dump, resulting in a clean 16.1 MHz beam structure injected into the ReA6 cryomodule.

TUP09 **Tuning and RF Measurements of the LILac RFQ**

H. Podlech *(IAP) B. Koubek (BEVATECH)*

A new linac for the NICA ion collider is being built in collaboration between JINR and BEVATECH GmbH. As first cavity the 2.5 m long RFQ was manufactured. Within this length it accelerates particles with a mass to charge ratio up to three to an energy of 600 keV/u. The operation frequency is 162.5 MHz and the 4-rod structure consists of 23 rf cells that need to be adjusted using tuning blocks in order to provide the required field distribution along the electrodes. The results of the tuning process as well as the overall rf setup of the RFQ are summarised in this paper.

TUP10 **High Power Tests of a New 4-Rod RFQ with Focus on its Thermal Stability**

S.R. Wagner*, D. Koser, H. Podlech (IAP) M. Basten (GSI) M. Basten (HIM) H. Podlech (HFHF)*

Due to strong limitations regarding operational stability of the existing HLI-RFQ a new design and prototype was commissioned. Three main problems were observed at the existing RFQ: A strong thermal sensitivity, modulated reflected power and insufficient stability of the contact springs connecting the stems with the tuning plates. Although the last problem was easily solved, the first two remained and greatly hindered operations. To resolve this issue and ensure stable injection into the HLI, a new RFQ-prototype, optimized in terms of vibration suppression and cooling efficiency, was designed at the Institute of Applied Physics (IAP) of Goethe University Frankfurt. To test the performance of this prototype, high power tests with more than 25 kW/m were performed at GSI. During those, it was possible to demonstrate operational stability in terms of thermal load and mechanical vibrations, calculating the thermal detuning and proof the reliability of the proposed design.

TUP11 **Upgrade and Operation of the ATLAS Radiation Interlock System (ARIS)**

***B.R. Blomberg**, B. Back, J.A. Clark, M.R. Hendricks, G. Savard, L. Weber (ANL)*

ATLAS (the Argonne Tandem Linac Accelerator System) is a super conducting heavy ion accelerator which can accelerate nearly all stable, and some unstable, isotopes between protons and uranium. Prompt radiation fields from gamma and or neutron are typically below 1 rem/hr at 30 cm, but are permitted up to 300 rem/hr at 30 cm. The original ATLAS Radiation Interlock System (ARIS) was installed 25 years ago. While it has been a functional critical safety system, its age has exposed the facility to high risk of temporary shutdown due to failure of obsolete components. Topics discussed will be architecture, hardware improvements, functional improvements, and operation permitting personnel access to areas with low levels of radiation.

TUP12 **Recent Upgrades and Improvements to the ATLAS Superconducting Accelerator**

***M.R. Hendricks**, B. Back, B.R. Blomberg, J.A. Clark, C. Dickerson, B. Mustapha, G. Savard, R.H. Scott, R.C. Vondrasek (ANL)*

ATLAS (the Argonne Tandem Linac Accelerator System) is a super conducting heavy ion accelerator which can deliver nearly all stable, and some unstable, isotopes between protons and uranium with a charge to mass range of 1/1 to 1/7. The maximum energy ranges of these ions are 7-17 MeV per nucleon with intensities ranging from a few thousand ions/second to microampere currents. This paper will focus on significant upgrades and expanded capabilities in the last several years, including a new ECR ion source, a radioactive in-flight separator, resonator upgrades, new target stations, and various subsystem improvements.

TUP13 **ATLAS 109 MHz Cryomodule Refurbishment**

***T.B. Petersen**, C. Dickerson, M. Kedzie, M.P. Kelly, T. Reid (ANL) A.F. Grabenhofer (Northern Illinois University)*

The last superconducting cryomodule of the Argonne Tandem Linear Accelerator System (ATLAS) is undergoing a significant upgrade to enable high intensity stable beams to the nuclear physics community with beam energies up to 10 MeV/u over the full mass range. Upgrades include the addition of an eighth superconducting cavity, reprocessing of the seven existing cavities by vacuum furnace baking to degas the niobium followed by a light electropolish, and replacement of the old reactive (VCX) fast tuners with new high power RF couplers, amplifiers and digital LLRF controls. The goal is to increase the available cryomodule accelerating voltage to 20 MV (2.5 MV/cavity) while enabling transport of high intensity beams with low losses. Performance at this level will constitute an advance in the present state-of-the-art for superconducting cavities in this range of β (0.15).

28 Jun – Tue

TUP14 **Study of Injection Line of the Cyclotrons C70XP of Arronax**

T. Durand, *R. Bellamy, C. Castel, F. Haddad, C. Koumeir, F. Poirier, H. Trichet (Cyclotron ARRONAX) T. Adam, P.G. Graehling, M. Heine, C. Maazouzi, F.R. Osswald (IPHC) F. Haddad (SUBATECH)*

The cyclotron C70XP is an accelerator built for the production of non-conventional radionuclides for nuclear medicine, research in physics, radio-chemistry and biology. Its injection section has been designed for 4 types of ions (HH^+, D^-, He^{2+} & H^-), 3 types of ions reach the end of the beamline (H^+, He^{2+} & D^+) at the maximum energy of 70 MeV (H^- & He^{2+}). It is important that regular and standard runs provide similar beam features with a good emittance quality. An investigation, focused on the beam in the injection, cover beam measurements and potential beam geometry constraints. The beam transverse characteristics in the injection line has been studied with an Allison-type emittance meter and a simple instrumented collimator installed inside the injection line. With these 2 devices, it is scrutinized how the beam emittance evolves as a function of settings of the injection magnets and the source parameters Dependencies found between the emittance, beam hotspots and tunings are discussed, as well as the protection performed by the collimator. Future of this work with a potential collimator design is introduced.

TUP15 **The LLRF and HLRF Systems Developments, in the General Frame of the K-800 Superconducting Cyclotron Upgrade at INFN-LNS**

A. Longhitano, *S. Aurnia, A.C. Caruso, G. De Luca, A. Spartà (INFN/LNS) L. Platania (LP Electronics di Platania Luca)*

The INFN-LNS has recently started the upgrade of the K-800 superconducting cyclotron and some acceleration facilities to extend research capabilities by increasing the beam power up to 10 kW. The RF system continuously updated over the years is also undergoing important improvements, also by taking benefit of the temporary shutdown of the machine. This article is focused on the Low Level system upgrade, which involves a more accurate management of all the RF parameters and a centralized control of the peripheral system on a single hardware platform. The new software update will optimize the interface with the main console control system. Another important point of this article is the refurbishment of the main power amplifier, in particularly the transition from the vacuum tube to the new solid state technology in the general upgrade of the High Level RF.

TUP16 **Seven Decades of Science with Accelerators at IPHC**

F.R. Osswald *(IPHC)*

The Institut Pluridisciplinaire Hubert Curien (IPHC) is a laboratory with solid foundations and perspectives to overcome future challenges. It is a component of the Centre National de Recherche Scientifique (CNRS) and the university of Strasbourg. It has been founded in 2006 after fusion of three local laboratories in the field of ecology/environment, chemistry and subatomic physics. The activities related with subatomic physics presents a rich history which goes back to the 40's and is now evolving towards new challenges at the frontier of the innovation with the contribution of other sciences as biology, chemistry, medicine and radiotherapy. The paper will recover a number of past and current activities with emphasis on the link between research and technology.

TUP17 **InnovaTron: A High-Intensity Self-Extracting Cyclotron for Medical Radioisotope Production**

G. D'Agostino, *W.J.G.M. Kleeven (IBA)*

At IBA a high-intensity compact cyclotron is being studied. The project is funded by the EU-H2020-MSCA programme. The beam from this cyclotron is extracted without using an extraction device (self-extraction). High extraction efficiency is obtained by special shaping of the magnetic field and the creation of large turn-separation. Proton currents up to 5 mA or more are expected, exceeding by far existing industrial cyclotrons, and opening a new way for large-scale production of medical radioisotopes. A major consideration for achieving high beam currents is space charge in the cyclotron center. We show results of FEM simulations that were done to find the plasma meniscus, the beam phase space and the extracted beam current from the chimney and of bunch formation and beam acceleration that were performed with our in-house tracking code AOC. The main features of the cyclotron are also presented.

TUP19 **First Tests of Model-Based Linac Phasing in ISAC-II**

S. Kiy, *R.A. Baartman*, *O.K. Kester*, *O. Shelbaya (TRIUMF)*

As the e-linac and ARIEL facilities at TRIUMF progress, the impending complexity of operating three simultaneous rare ion beams (RIBs) approaches. To help prepare for this, a framework for the development of High Level Applications has been constucted, upon which multiple avenues for improvement towards model-based and automated tuning are being pursued. Along one of these avenues, the 40-cavity superconducting ISAC-II heavy ion linac has been studied and modelled in the envelope code transoptr. This has allowed for real-time integration through the on-axis fields, fitting focal strengths of solenoids to achieve desired beam waists, and calculation of necessary cavity phases to achieve a desired output energy for given input beam parameters. Initial tests have been completed, successfully phasing up to 37 cavities using the transoptr model and achieving a final output energy within 1% of the expected while maintaining nominal (>90%) transmission. A summary of the calibration of the model to the machine is given, followed by results of the phasing tests and an outlook towards future improvements.

WE1 — Wednesday Session 1

WE1N1 09:30 35

Welcome by the Technical Managing Director of GSI and FAIR

J. Blaurock *(FAIR)*

Welcome by the Technical Managing Director of GSI and FAIR

WE1I2 09:35 30

Status of the FAIR Facility

P.J. Spiller *(GSI)*

The speaker did not provide an abstract.

WE1I3 10:05 30

FRIB at MSU: Status and Opportunities/Commissioning Experience at FRIB

P.N. Ostroumov *(FRIB)*

The Facility for Rare Isotope Beams (FRIB), a major nuclear physics facility for research with fast, stopped and reaccelerated rare isotope beams, was successfully commissioned, and it is in operations. The acceleration of Xe, Kr, and Ar ion beams above 210 MeV/u using all 46 cryomodules with 324 superconducting cavities was demonstrated. Several key technologies were successfully developed and implemented for the world's highest energy continuous wave heavy ion beams, such as full-scale cryogenics and superconducting radiofrequency resonator system, stripping heavy ions with a thin liquid lithium film, and simultaneous acceleration of multiple-charge-state-heavy ion beams. In December 2021, we demonstrated the production and identification of Selenium-84 isotopes and, in January 2022, commissioned the fragment separator by delivering 210 MeV/u argon beam to the focal plane. The first experiments with primary Ca, Se and Zn beams are scheduled for May-July, 2022.

WE1I4 10:35 30

Innovation Aspects in Future Accelerators for Hadron Therapy

E. Benedetto *(SEEIIST) M. Vretenar (CERN)*

Modern accelerators for hadron therapy need to provide high intensity beams for innovative dose-delivery modalities such as FLASH, pencil beams for 3D scanning, as well as multiple ions for profiting of their different radio-biological properties. They need to be compact, cheap and have a reduced energy footprint. At the same time, they need to be reliable, robust and simple to operate. Cyclotrons (and compact synchrotrons) are nowadays the standard for proton therapy. For heavier ions such as carbon, synchrotrons remain the most viable option, together with the development of full-linac and FFA solutions. Concerning medical synchrotrons, new European initiatives study the feasibility of advanced multi-turn injection (including a new linac dimensioned to produce medical radioisoptopes in parallel) and advanced extraction modalities. Moreover, an innovative synchrotron for carbon ions, equipped with superconducting magnets, and a compact synchrotron optimized for helium ions, making use of proven normal-conducting technology, are being designed.

WE2 — Wednesday Session 2

WE2I1
11:30 30

The New GANIL Beams: Commissioning of SPIRAL 2 Accelerator and Resent Developments

***H. Franberg Delahaye**, R. Ferdinand (GANIL) R. Ferdinand (CEA-DRF-IRFU)*

The GANIL installation at Caen in France has been operating with warm temperatures cyclotrons for heavy ion beam physics since 1983. The accelerated stables beams widely ranges from Carbon to Uranium beams. Low energy and post accelerated radioactive ion beams are also being provided. The GANIL laboratory has newly increased their different ion beams available with the installation and commissioning of a superconducting linear accelerator ' SPIRAL 2 and its experimental areas. The construction started in 2011, the first beam was extracted at low energy in late 2014 with pre-acceleration in 2017 and since 2019 the new installation delivers beam for nuclear physics experiments. This paper will cover the commissioning of the SPIRAL 2 installation at GANIL with its superconducting LINAC - but also the latest development of stable and radioactive beams at the cyclotrons.

WE2I2
12:00 30

Status and Challenges of High Intensity Heavy Ion Accelerator Facility (HIAF) in China

***J.C. Yang**, L.T. Sun, J.W. Xia, G.Q. Xiao, H.S. Xu, Y.J. Yuan, H.W. Zhao, X.H. Zhou (IMP/CAS) L.T. Sun (UCAS) W.-L. Zhan (CAS)*

HIAF is a proposed new accelerator facility for advances in the nuclear physics and related research fields in China. The HIAF facility plan was approved by central government of China in December 2012 and now is under construction. The construction of the accelerator complex began in 2018 and is scheduled to be complete by the end of 2025. A series of new and innovative technologies have adopted for technical challenges and critical issues for the varication of the feasibility, reliability and performance of HIAF. In the past several years, the prototypes have been developed successfully for these innovative technologies,such as superconducting 45GHz ECR ion source, innovative fast cycling power supply based on full-energy storage principle, ceramic-lined thin wall vacuum chamber and magnetic alloy core loaded cavity. The machine design was optimized based on these prototypes developments, details of technical design has been finished and some hardware systems already go into production. The construction of civil construction and common system are also going smoothly. The progress and present status will be given in the presentation.

TH1 — Thursday Session 1

TH1I1
09:00 30

nuCARIBU: Upgrade of the CARIBU Facility at Argonne

***G. Savard**, C. Dickerson, J.A. Nolen, J. Song (ANL)*

The CARIBU facility at Argonne National Laboratory has been providing to users low-energy and reaccelerated beams of neutron-rich fission fragments for about a decade. These were obtained from a gas catcher system thermalizing fission fragments from a roughly 1 Ci 252Cf source that were then extracted as a low-energy beam that is purified by successive mass separation in a high-resolution separator and an MR-TOF system. While the system provided world unique beams, obtaining the required thin 252Cf source turned out to be an unreliable process that has hampered sustained operation. To remedy this situation, CARIBU is now being upgraded to nuCARIBU that will use a neutron-generator system to induce neutron-induced fission on a thin foil of 235U located inside the gas catcher. This will provide a more controllable source of fission products and a roughly order of magnitude improvement in total yield. The neutron generator is based on the (p,7Li) reaction with the beam from a compact high-intensity 6 MeV cyclotron hitting a high-power solid lithium target surrounded by a moderator. The nuCARIBU system, its expected performance, connection to ATLAS and current status will be presented.

TH1I2
09:30 30

Reinforcement Learning and Bayesian Optimization for Ion Linac Operations

***J.L. Martinez Marin**, B.R. Blomberg, C. Dickerson, B. Mustapha, D. Stanton (ANL)*

The Argonne Tandem Linear Accelerator System (ATLAS) is a DOE/NP User Facility for studying low-energy nuclear physics with heavy ions. It operates ~6000 hours per year. The facility uses three ion sources and services six target areas at energies from ~1–15 MeV/u. To accommodate the total number of approved experiments and their wide range of beam-related requirements, ATLAS reconfigures once or twice per week over 40 weeks of operation per year. The startup time varies from ~12' to 48 hours depending on the complexity of the tuning, which will increase with the upcoming Multi-User Upgrade designed to deliver beam to two experimental stations simultaneously. The use of artificial intelligence can significantly reduce the time needed to tune the accelerator. After establishing automatic data collection procedures and analyzed the data, we have developed, and tested machine learning models to tune and control the machine. Models based on Reinforcement Learning (RL) and Bayesian Optimization (BO) will be presented and their performance compared and discussed. RL and BO are well known AI techniques, often used for control systems. The results will be presented for a subsection of ATLAS that contains complex elements such as the radio-frequency quadrupole. The models will be later generalized to the whole ATLAS linac, and similar models can be developed for any accelerator with a modern control system.

TH1C3
10:00 20

Automation of RF and Cryomodule Operation at FRIB

S. Zhao, *E. Bernal, W. Chang, E. Daykin, E. Gutierrez, W. Hartung, S.H. Kim, S.R. Kunjir, T.L. Larter, D.G. Morris, J.T. Popielarski, H.T. Ren, T. Xu (FRIB)*

The Facility for Rare Isotope Beams (FRIB) has been commissioned, with rare isotopes first produced in December 2021 and first user experiments conducted in May 2022. The FRIB driver linear accelerator (linac) uses 6 room temperature cavities, 324 superconducting cavities, and 69 superconducting solenoids to accelerate ions to more than 200 MeV/nucleon. Because of the large scale, automation is essential for reliable linac operation with high availability. Automation measures implemented during linac commissioning include turn-on of the cavities and solenoids, turn-on and fast recovery for room temperature devices, and emergency shut down of linac devices. Additional automated tasks include conditioning of multipacting barriers in the cavities and calibration of the control valves for the pneumatic tuners. To ensure a smooth transition to operations, we are currently working on real-time health monitoring of the linac cryomodules, including critical signals such as X-ray levels, RF coupler temperatures, and cryogenic parameters. In this paper, we will describe our automation procedures, the implementation details, and the experience we gained.

TH1C4
10:20 20

Cavity Designs for the CH3 to CH11 and Bellow Tuner Investigation of the Superconducting Heavy Ion Accelerator HELIAC at GSI

T. Conrad, *H. Podlech, M. Schwarz (IAP) K. Aulenbacher, W.A. Barth, F.D. Dziuba, T. Kürzeder, S. Lauber, J. List, M. Miski-Oglu (HIM) K. Aulenbacher (IKP) W.A. Barth, M. Basten, F.D. Dziuba, V. Gettmann, M. Heilmann, T. Kürzeder, S. Lauber, J. List, M. Miski-Oglu, A. Rubin, A. Schnase, S. Yaramyshev (GSI)*

New CH-DTL cavities designs of the planned Helmholtz Linear Accelerator (HELIAC) are developed in collaboration of GSI, HIM and IAP Frankfurt. The in cw-mode operating linac with a final energy of 7.3 MeV/u, is intended for various experiments, in particular with heavy ions at energies close to the Coulomb barrier for research on SHE. Twelve sc CH cavities are foreseen, divided into four different cryostats each equipped with two dynamic bellow tuner. After successful beam tests with CH0, CH3 to CH11 were designed. Based on the experience gained so far, optimizations were made, which will lead to both an increase in performance in terms of reducing the peak fields limiting superconductivity and a reduction in manufacturing costs and time. In order to optimize manufacturing, attention was paid to design many parts of the cavity, such as lids, spokes, tuner and helium shell, with the same geometrical dimensions. In addition, a tuner test rig was developed, which will be used to investigate the mechanical properties of the bellow tuner. For this purpose, different simulations were made in order to realize conditions as close as possible to reality in the test rig.

TH2 — Thursday Session 2

TH2I1
11:10 30

Recent Progress of Research and Development for the Cost Effective, Energy Efficient Proton Accelerator CYCIAE-2000

T.J. Zhang, C. Wang (CIAE)

The MW class proton accelerators are expected to play important role in many fields, attracting institutions to continue research and tackle key problems. The CW isochronous accelerator obtains high power beam with higher energy efficiency, which is very attractive to many applications. Scholars generally believe that the energy limitation of the isochronous cyclotron is ~1 GeV. In order to get higher beam power by the isochronous machine, enhancing the beam focusing become the most important issue. Adjusting the radial gradient of average magnetic field make the field distribution match the isochronism. When we adjust the radial gradient of peak field Bhill, the first order gradient is equivalent to the quadrupole field, the second order, to the hexapole field, and so on. Just like the synchrotron, there are quadrupole, hexapole magnet and so on, along the orbits so as to get higher energy, as all we know. If we adjust the radial gradient for peak field of an FFAG's FDF lattice, and cooperate with the angular width (azimuth flutter) and spiral angle (edge focusing) of the traditional cyclotron pole, we can control the working path in tune diagram very flexibly. During enhancing the axial focusing, the beam intensity and energy of CW isochronous accelerator are significantly increased. And a 2 GeV CW FFAG with 3mA of average beam intensity are designed. It is essentially an isochronous cyclotron although we use 10 folder of FDF lattices. The key difficulty is that the magnetic field and each order of gradient should be accurately adjusted in a large radius range. As a high power proton accelerator with high energy efficiency, we adopt high temperature superconducting (HTS) technology for the magnets. 15 RF cavities with Q value of 90000 provide energy gain per turn of ~15 MeV to ensure the CW beam intensity reaches 3 mA. A 1:4 scale, 15 ton HTS magnet and a 1:4 scale, 177 MHz cavity have been completed. The results of such R & D will also be presented in this paper.

TH2I2
11:40 30

Longitudinal Beam Diagnostics R&D at GSI-UNILAC

R. Singh (GSI)

GSI UNILAC provides a wide variety of ion types from energies ranging from 1.4 MeV/u to ~12 MeV/u with a large dynamic range in the beam intensities either directly to the experimental users or to the upstream accelerators. This flexibility in beam parameters requires a constant tuning of the machine parameters for optimal operation of the UNILAC. Therefore, there has been a constant and pressing need for operationally convenient, accurate, fast and potentially non-destructive beam diagnostics for longitudinal time profile and energy distribution. This contribution discusses the recent progress on longitudinal charge profile distribution measurements at GSI UNILAC. A comparison is given between the outcome of recent methods like transition radiation in GHz regime, Fast Faraday cups (FFCs) to the older methods such phase pick-ups as well as RF deflectors coupled with single particle detectors.

TH2C4
12:30 20

Signal Estimation and Analayzing of Cold Button Bpms for a Low-Beta Helium/Proton Superconducting Linac

***Y. Zhang**, X.J. Hu, H. Jia, Z.X. Li, S.H. Liu, H.M. Xie (IMP/CAS)*

We develop a formula including the low-beta effect and the influence of long cable issues for estimating the original signal of cold BPMs. A good agreement between the numerical and the measured signal with regard to two kinds of beam commissioning, helium and proton beams, in a low-beta helium and proton superconducting linac, proves that the developed numerical model could accurately estimate the output signal of cold button BPMs. Analysing the original signal between the first and the last cold BPM in the cryomodule, it is found that the signal voltage in the time domain is increased with the accelerated beam energy. However, the amplitude spectra in the frequency domain has more high frequency Fourier components and the amplitude at the first harmonic frequency reduces a lot. It results in a decline of the summed value from the BPM electronics. The decline is not proportional to a variety of the beam intensity. This is the reason why BPMs give only relative intensity and not absolute value for low-beta beams with a Gaussian distribution.

TH3 — Thursday Session 3

TH3I1
14:00 30

A Novel CW RFQ for Exotic and Stable Beams

***A. Palmieri**, L. Bellan, M. Comunian, L. Ferrari, A. Pisent, C.R. Roncolato (INFN/LNL)*

The SPES RFQ is designed in order to accelerate beams in CW with A/q ratios from 3 to 7 from the Charge Breeder through the MRMS and the selection and injection lines up to the MEBT (Medium Energy Beam Transport). The RFQ is composed of 6 modules about 1.2 m long each. Each module is basically composed of a Stainless Steel Tank and four OFE Copper Electrodes (obtained by brazing of two subassemblies in order to spare material). A copper layer is plated on the tank inner surface and a spring joint between tank and electrode is used in order to seal the RF. In this contribution, the main design steps of the RFQ, the construction concepts and the results obtained for the first assembled modules are shown.

TH3C2
14:30 20

Alternating Phase Focusing Based DTL for Heavy Ion Application

***S. Lauber**, K. Aulenbacher, W.A. Barth, M. Basten, C. Burandt, F.D. Dziuba, V. Gettmann, T. Kürzeder, J. List, M. Miski-Oglu, S. Yaramyshev (GSI) K. Aulenbacher, W.A. Barth, M. Basten, C. Burandt, F.D. Dziuba, V. Gettmann, T. Kürzeder, **S. Lauber**, J. List, M. Miski-Oglu (HIM) K. Aulenbacher, W.A. Barth, F.D. Dziuba, **S. Lauber**, J. List (KPH)*

The continuous wave (CW) operated HElmholtz LInear ACcelerator (HELIAC) is going to reach the next milestone with the commissioning of the superconducting (SC) Advanced Demonstrator cryomodule, comprising four SC Crossbar H-mode (CH) cavities and SC steerer magnets. In parallel with the commissioning of the SC main accelerator, the normal conducting injector consisting of an ECR ion source, a RFQ and two Interdigital H-mode (IH) cavities will be built based on an Alternating Phase Focusing (APF) beam dynamics scheme. Both IH cavities will provide a beam energy gain from 300 keV/u to 1400 keV/u with a maximum mass to charge ratio of 6, requiring only one external quadrupole triplet and a beam corrector element between them. The APF concept allows stable and effective beam transport with transverse and longitudinal focusing, enabling an efficient and compact design. Due to the stringent requirements of the APF concept on the voltage distribution and the CW operation, optimization of each cavity in terms of RF, mechanical and thermal properties is crucial for successful operation of the HELIAC injector. The current layout of the APF based and CW operated injector will be presented.

TH3C3
14:50 20

Recent UNILAC Upgrade Activities

***U. Scheeler**, W.A. Barth, M. Miski-Oglu, H. Vormann, M. Vossberg, S. Yaramyshev (GSI) W.A. Barth (HIM)*

The GSI UNILAC is the section of the GSI accelerator facility that has been in operation the longest. UNILAC is able to accelerate ions from hydrogen to uranium up to 20 MeV (p^+) and 13 MeV/u (uranium). The main focus of the recent upgrade measures is to meet the FAIR requirements and to provide reliable and longterm beam operation conditions. Besides post stripper upgrade and upgrade of the UNILAC controls, a particular attention is payed to improve the performance of the High Current Injector and to intensify spare part management for the aging accelerator. Extensive spare part management and replacement of outdated equipment is the main direction to ensure operational reliability. In order to improve the UNILAC-performance modified beam dynamics designs for the frontend system and the use of advanced technologies are needed. Among other things, a modified Low and Medium Energy Beam Transport section for the HSI and reliable (non-destructive) high intensity beam diagnostics devices are in progress. This paper addresses the status of current development efforts and specific plans for the UNILAC upgrade.

TH4 — Thursday Session 4

TH4C1
15:50 20

Status and Perspectives of the Advanced Ion Source for Hadrontherapy (AISHa)

O. Leonardi, *G. Castro, L. Celona, F. Chines, S. Gammino, A. Massara, L. Neri, S. Passarello, R. Reitano, D. Siliato (INFN/LNS) G. Costanzo (INFN-Pavia) L. Malferrari, F. Odorici (INFN-Bologna) C. Maugeri, F. Russo (CNAO Foundation) R. Reitano (Università degli Studi di Catania)*

The Advanced Ion Source for Hadrontherapy (AISHa) is a compact electron cyclotron resonance ion source (ECRIS) operating at 18 GHz designed and developed to generate high brightness multiply charged ion beams for hadrontherapy purposes. Its peculiarities make AISHa also a suitable choice for research and industrial applications. AISHa is able to produce more than 1400 μA O^{6+}, 500 μA C^{4+}, 5 mA He^{2+}. In the framework of the INSpIRIT program and in collaboration with CNAO and GSI, new ion beam candidates for cancer treatment and material irradiation are being developed. A copy of the AISHa ion source is also being installed at CNAO to expand its potential in terms of ion beam production. AISHa is also the test-bench for several R&D activities to increase ion source performance and for non-invasive plasma diagnostic purposes: an innovative active plasma chamber designed to increase plasma confinement by modifying plasma losses fluxes is under study together with a dedicated Optical Emission Spectroscopy diagnostics setup. In this work, we will discuss the status of AISHa together with the description of the forthcoming developments and perspectives.

TH4C3
16:30 20

High Intensity Proton Beams at GSI (Heavy Ion) UNILAC

W.A. Barth, *M. Miski-Oglu, U. Scheeler, H. Vormann, M. Vossberg, S. Yaramyshev (GSI)* ***W.A. Barth***, *M. Miski-Oglu (HIM)*

A significant part of the experimental program at FAIR is dedicated to pbar physics requiring a high number of cooled pbars per hour. The primary proton beam has to be provided by a 70 MeV proton linac followed by two synchrotrons. The new FAIR proton linac will deliver a pulsed high intensity proton beam of up to 35 mA of 36 μs duration at a repetition rate of 4 Hz. The GSI heavy ion linac (UNILAC) is able to deliver intense heavy ion beam for injection into SIS18, but it is not suitable for FAIR relevant proton beam operation. In an advanced machine investigation program it could be shown, that the UNILAC is able to provide for sufficient high intensities of CH3-beam, cracked (and stripped) in a supersonic nitrogen gas jet into protons and carbon ions. This new operational approach results in up to 3 mA of proton intensity at a maximum beam energy of 20 MeV, 100 μs pulse duration and a rep. rate of 4 Hz. For some time now, UNILAC proton beam operation with higher intensities has been offered as standard for users. Recent linac beam measurements will be presented, showing that the UNILAC is able to bridge the time until the FAIR-proton linac delivers high-intensity proton beams.

FR1 — Friday Session 1

FR1I1 09:00 30

Design Status of the EIC/Electron Ion Collider Design and Path Forward

F.J. Willeke *(BNL)*

The speaker did not provide an abstract.

FR1C2 09:30 20

Redundancy Concepts for Improved MTBF of RF Systems in Particle Accelerator Facilities

M. Lau*, R. Heilig, D. Hollmann, M. Schweizer, J. Weber (TRUMPF Huettinger GmbH) M. Beyer (HBH Microwave GmbH)*

System availability and reliability are key for particle accelerator facilities. The risk of downtime is directly correlated to the performance of crucial components, e.g the RF technology. Therefore, measures are required for avoiding any unwanted system failure. One of our approaches to drastically improve the MTBF of our Solid State Power Amplifier is providing different levels of redundancy of crucial and critical components. Here we want to present the influence of different redundancy levels on the MTBF of Solid State Power Amplifier Systems by increasing the number of transistors and power supplies in a modular design. By this design we can provide customized solutions meeting the individual demand on reliability for particle accelerators. Since the to be expected MTBF of RF amplifier is usually not correlated to redundancy levels we try to follow an approach by reaching different values of the predicted MTBF by adapting the number of transistors used.

FR1C3 09:50 20

Mode Analysis of Single Spoke Resonator Type-2 (SSR2) for RISP

M.O. Hyun *(IBS)*

Rare Isotope Science Project (RISP) in the Institute of Basic Science (IBS), Daejeon, South Korea, is developing the high-energy superconducting(SC) linac composed with two types of superconducting cavity, single spoke resonator typs^{-1} (SSR1) and type-2 (SSR2). Both cavities have same frequency 325MHz, but different beta, 0.3 and 0.51 each. For operating SC cavity within the target frequency, all outer disturbances should be removed or avoided. As a view of mechanical vibration, comparably low frequency up to 20kHz always happens as a consequence of combination between outer disturbance and resonant frequency of SC cavity. In this paper, we will show the design layout of SSR2 and its specifications. And also the mechanical resonance analysis for both bare and dressed cavity will be analyzed with numerical analysis program.

FR2 — Friday Session 2

FR2I1
10:40 30

First Intense Beam at JUNA 400 kV Underground Accelerator

***L.T. Sun**, J.Q. Li, J.L. Liu, Y.G. Liu, X.D. Tang, P.P. Wang, Q. Wu, H.W. Zhao (IMP/CAS) L.H. Chen, B.Q. Cui, B. Guo, J.H. Li, G. Lian, W.P. Liu (CIAE) J.J. He (BNU)*

Featuring about 2400 m marble overburden, Jinping Underground laboratory for Nuclear Astrophysics (JUNA) provides the optimum experimental conditions for the key reactions of nuclear astrophysics, i.e. $^{12}C(\alpha,\gamma)^{16}O$, $^{13}C(\alpha,n)^{16}O$, $^{25}Mg(p,\gamma)^{26}Al$ and $^{19}F(p,\alpha)^{16}O$. The ion beams used in the experiments are delivered by a 400 kV high voltage platform, with the designed beam intensities of 10 emA H^+, 10 emA He^+ and 2 emA He^{2+} that are produced with Electron Cyclotron Resonance (ECR) ion sources. JUNA accelerator had been successfully commissioned at underground lab and used for experimental investigations with a total operation time of more than 2,000 hours in early 2021. This paper will review the development of JUNA accelerator. High quality intense ion beam production, acceleration and transmission to the target area will be presented.

FR2N3
11:30 30

Physics with Heavy Ion Accelerators

***M. Block** (GSI)*

The speaker did not provide an abstract.

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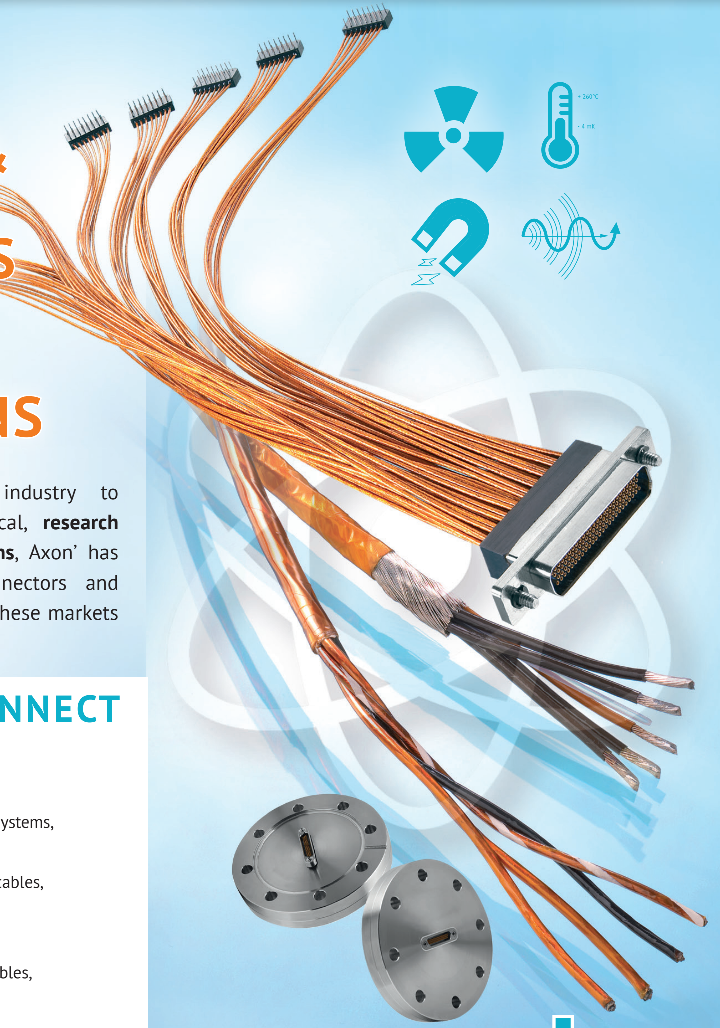

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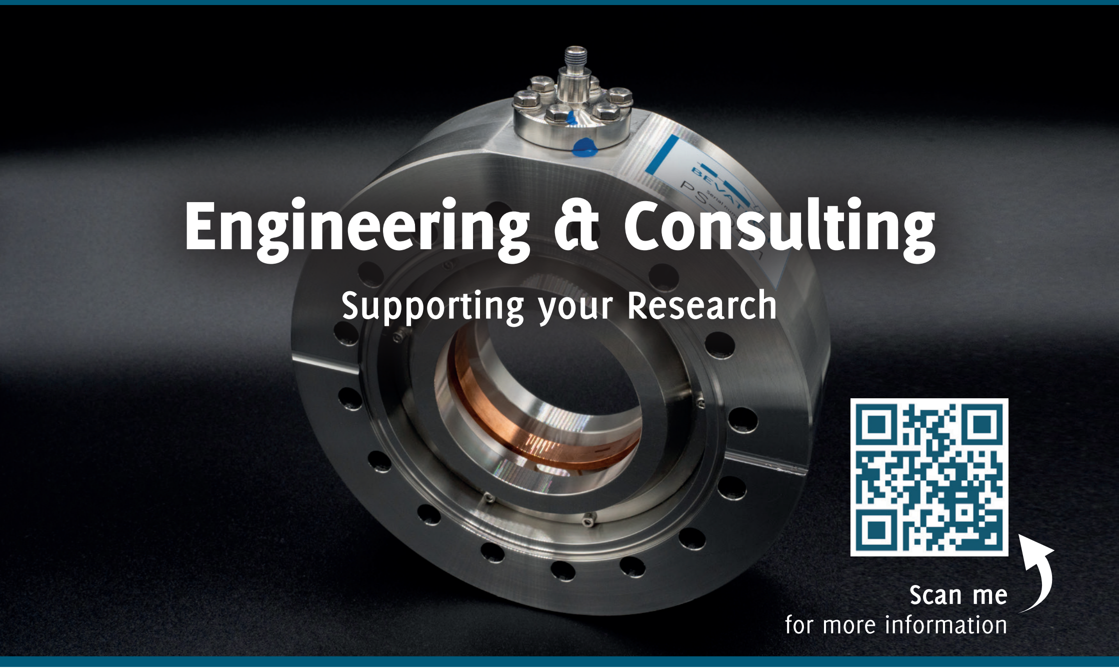
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