57th ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams

Workshop Programme and Abstracts

Scandic Triangeln Hotel, Malmö, Sweden
2016 July 3-8

1 Welcome to HB2016

Welcome to Malmö and to the 57^{th} ICFA advanced beam dynamics workshop on high-intensity and high-brightness hadron beams.

HB, High-Brightness High-Intensity Hadron Beams workshop series is and has been a network for scientists and engineers involved in the study, design, development or operation of hadron accelerators.

Since the first HB within the ICFA's (International Committee for Future Accelerators) ABDW (Advanced Beam Dynamics Workshops) series, there has been a giant leap in the size and power of high intensity hadron accelerators, and our community has successfully broken one record after another. At the time of the first HB, the highest power accelerator had not yet reached a megawatt of power; today we have accelerators operating above 1 MW, making the hard challenges look easy. On the energy frontier we have passed the 10 TeV (c.o.m.) energy for protons and the 1 PeV for ions. This wouldn't have been possible without extensive study of the beam dynamics, halo production mechanisms, developments in diagnostics devices, loss measurement and activation, and of course the availability of high power targets. Today our community

is proposing accelerators with powers above 10 MW, and to make that proposal a reality; we should look at how we made it past the MW threshold and see how to take the next steps. The HB has been and still is the forum to discuss our ideas, cherish our successes together, and share our failures and the lessons we have learned from them.

The HB starts with a day of plenary talks, and the first day ends with a poster session. In the next three days two sessions will be held in parallel, covering Beam Dynamics in Rings (WG-A), Beam Dynamics in Linacs (WG-B), Accelerator Systems (WG-C), Commissioning and Operations (WG-D) and Beam Instruments and Interactions (WG-E). On the last day of the workshop there will be a plenary summary and discussion on parallel sessions and we will end the workshop with a bus tour (optional to participate) to the ESS construction site (WG-E). The program of the HB is set by the International Organizing Committee (IOC), which also selects the plenary speakers and working group conveners. The speakers of the parallel sessions are invited by the working group conveners and are selected from the submitted abstracts. These committees have done an excellent work in setting up the program, and without their help this workshop would have been impossible.

Malmö is the third largest city in Sweden though small compared to many cities in

the rest of the world. On the other hand Malmö is home to people from more than 175 nationalities, is an eco-friendly city and one of the greenest cities in Europe.

We very much look forward to your active participation in the workshop. Once again, welcome to Malmö and HB2016.

Mamad Eshraqi
HB2016 Chairman

2 Committees

International Organizing Committee

Mohammad Eshraqi	(ESS, Sweden)	mohammad.eshraqi@esss.se
Alex Chao	(SLAC, USA)	achao@slac.stanford.edu
Andrea Pisent	(INFN, Italy)	andrea.pisent@lnl.infn.it
Bill Weng	(BNL, USA)	weng@bnl.gov
Christopher Prior	(RAL, UK)	chris.prior@stfc.ac.uk
Hideaki Hotchi	(J-PARC, Japan)	hotchi.hideaki@jaea.go.jp
Hongwei Zhao	(IMP, China)	zhaohw@impcas.ac.cn
In Soo Ko	(Postech, Korea)	isko@postech.ac.kr
Ingo Hofmann	(GSI, Germany)	i.hofmann@gsi.de
Jean-Michel Lagniel	(GANIL, France)	jean-michel.lagniel@ganil.fr
Ji Qiang	(LBL, USA)	jqiang@lbl.gov
Ji-Ho Jang	(IBS, Korea)	jhjang@ibs.re.kr
Jia-er Chen	(Peking University, China)	chenje@pku.edu.cn
Jie Wei	(FRIB, USA)	wei@frib.msu.edu
Jingyu Tang	(IHEP, China)	tangjy@ihep.ac.cn
Jiuqing Wang	(IHEP, China)	wangjq@ihep.ac.cn
John Galambos	(ORNL, USA)	galambosjd@ornl.gov
Jose Manuel Perez	(CIEMAT, Spain)	jm.perez@ciemat.es

Lawrence Rybarcyk	(LANL, USA)	lrybarcyk@lanl.gov
Mike Seidel	(PSI, Switzerland)	mike.seidel@psi.ch
Ronald Davidson	(PPPL, USA)	rdavidson@pppl.gov
Sergey Ivanov	(IHEP, Russia)	sergey.ivanov@ihep.ru
Shinian Fu	(IHEP, China)	fusn@ihep.ac.cn
Simone Gilardoni	(CERN, Switzerland)	simone.gilardoni@cern.ch
Srinivas Krishnagopal	(Bhabha, India)	skrishnagopal@gmail.com
Stephen Holmes	(FNAL, USA)	holmes@fnal.gov
Thomas Roser	(BNL, USA)	roser@bnl.gov
Todd Satogata	(JLAB, USA)	satogata@jlab.org
Weiren Chou	(FNAL, USA)	chou@fnal.gov
Yong Ho Chin	(KEK, Japan)	yongho.chin@kek.jp
Yoshi Mori	(Kyoto University, Japan)	mori@rri.kyoto-u.ac.jp
Yoshishige Yamazaki	(FRIB, USA)	yamazaki@frib.msu.edu

Conveners

WG-A: Beam Dynamics in Rings

Giuliano Franchetti	(GSI, Germany)	g.franchetti@gsi.de
Wolfram Fischer	(BNL, USA)	wfischer@bnl.gov
Yong Ho Chin	(KEK, Japan)	yongho.chin@kek.jp

WG-B: Beam Dynamics in Linacs

Alessandra Lombardi	(CERN, Switzerland)	alessandra.lombardi@cern.ch
Masanori Ikegami	(FRIB, USA)	ikegami@frib.msu.edu
Yuan He	(IMP, China)	hey@impcas.ac.cn

WG-C: Accelerator Systems

Sarah Cousineau	(SNS, USA)	scousine@ornl.gov
Jean-Luc Biarrotte	(CNRS-IN2P3, France)	biarrott@ipno.in2p3.fr
Sheng Wang	(IHEP, China)	wangs@ihep.ac.cn
Luc Perrot	(IN2P3, France)	perrot@ipno.in2p3.fr

WG-D: Commissioning and Operations

Fernanda Garcia	(FNAL, USA)	fgarcia@fnal.gov
Angelina Parfenova	(PSI, Switzerland)	angelina.parfenova@psi.ch
Hideaki Hotchi	(JAEA, Japan)	hotchi.hideaki@jaea.go.jp

WG-E: Instrumentation and Beam Interactions

Michiko Minty	(BNL, USA)	minty@bnl.gov
Hee Seock Lee	(Postech, Korea)	lee@postech.ac.kr
Tom Shea	(ESS, Sweden)	thomas.shea@esss.se

Local Organizing Committee

Abril Qaraeen	(ESS, Sweden)	abril.qaraeen@esss.se
Danéle Gous	(ESS, Sweden)	danele.gous@esss.se
Garry Trahern	(ESS, Sweden)	garry.trahern@esss.se
Henno Gous	(ESS, Sweden)	henno.gous@esss.se
Inga Tejedor	(ESS, Sweden)	inga.tejedor@esss.se
Johan Olander	(ESS, Sweden)	johan.olander@esss.se
Juliana Pranke	(ESS, Sweden)	juliana.pranke@esss.se
Mikael Johansson	(ESS, Sweden)	mikael.johansson@esss.se
Mohammad Eshraqi	(ESS, Sweden)	mohammad.eshraqi@esss
Ryoichi Miyamoto	(ESS, Sweden)	ryoichi.miyamoto@esss.se
Søren Pape Møller	(Aarhus University, Denmark)	fyssp@phys.au.dk
Theodor Lindquist	(ESS, Sweden)	theodor.lindquist@esss.se
Yngve Levinsen	(ESS, Sweden)	yngve.levinsen@esss.se
Alexander Lauge Pedersen	(ESS, Sweden)	alexander.laugepedersen@
Oscar Elmqvist Sandvik	(ESS, Sweden)	oscar.elmqvistsandvik@gm

Editorial Team

3 Useful Information

Official language

The language of the workshop is English.

Time

Sweden time is the Central European Time (GMT+2), current time zone offset during daylight saving time.

Climate

Dress code during the workshop is business casual and casual on the excursion. Contrary to common belief Sweden is not that cold; that is why ESS still needs a cryogenics system! Malmö has a record high temperature of 33.2 °C in July. But to manage the expectations it is good to know that the average is 20 to 23°C and the average low is 14°C. Average precipitation in July is ~ 60 mm, and the abundance of wind turbines around Malmö is a good sign that it is a reasonably windy city. Because of its northern latitude the daylight exceeds 16 hours July.

Currency and Credit Cards

Swedish crown, krona (SEK) is the currency used in Sweden. If you are paying with cash the bill will be rounded to nearest SEK. If you use your credit/debit card exact amount is used. All major credit cards are accepted in shops, taxis and cash machines. Exceptions are some small shops, minor taxi companies and buses. Sometimes American Express cards might not be accepted. Sweden is becoming a cash less society rapidly, please note that there might be stores where no cash is accepted, only payments by cash or credit card. 9.4 SEK = 1 EUR, 8.5 SEK = 1 USD (2015-June to 2016-June (Max+Min)/2)

Emergency Number

112

Public Transport

One cannot purchase public transport tickets on board; the tickets should be bought before boarding. Buses accept neither cash not credit card payments.

Tipping

Tips in bars and restaurants are already included in the bill. Anything extra is of course appreciated by the personnel. It is not uncommon to round up your bill. All prices in shops are including the value added tax (MOMS in Swedish, which is 25%). Tipping taxi drivers is also a common practice.

Electricity

Type C and type F plugs are used in Sweden, these are the same type which is commonly used in Europe, South America & Asia. They have 2 round pins and almost always are 220 to 240 V at 50 Hz.

Workshop Policies

Disclaimer

The organisers are not liable for damages and/or losses of any kind which may be incurred by the conference delegates or by any other individuals accompanying them, both during the official activities as well as going to/from the conference. Delegates are responsible for their own safety and belongings.

HB2016 Anti-harassment Policy

HB2016 is dedicated to providing a harassment-free experience for everyone. We do not tolerate harassment in any form. Participants violating this rule may be sanctioned or expelled from the workshop without a refund at the discretion of the conference organisers. Harassment includes:

- offensive verbal comments related, but not limited to: gender, gender identity and expression, sexual orientation, disability, physical appearance, body size, race, religion;
- sexual images in public spaces;
- deliberate intimidation, stalking, following, harassing photography or recording;

- sustained disruption of talks or other events;
- inappropriate physical contact, and unwelcome sexual attention.

Participants asked to stop any harassing behaviour are expected to comply immediately.

Exhibitors in the Industrial Exhibition are also subject to the anti-harassment policy. In particular, exhibitors should not use sexualised images, activities, or other material. Booth staff (including volunteers) should not use sexualised clothing/uniforms/costumes, or otherwise create a sexualised environment.

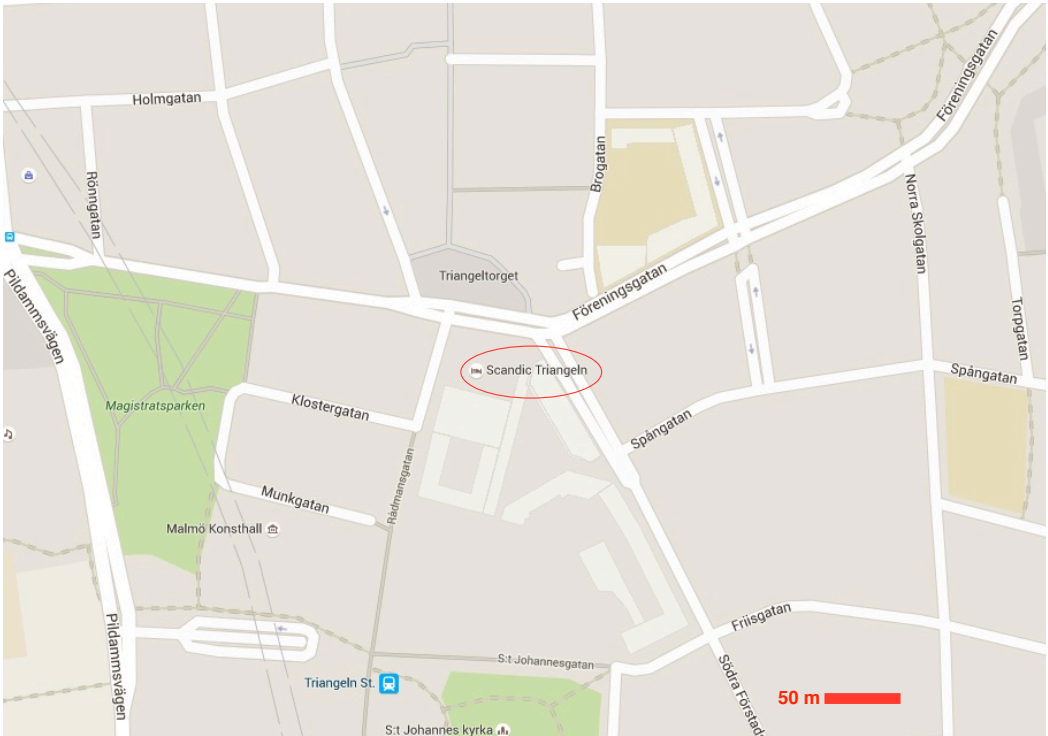
If a participant engages in harassing behaviour, the workshop organisers may take any action they deem appropriate, including warning the offender or expulsion from the conference with no refund. If you are being harassed, notice that someone else is being harassed, or have any other concerns, please contact a member of organising staff immediately. Organising staff will be happy to help participants contact hotel/venue security or local law enforcement, provide escorts, or otherwise assist those experiencing harassment to feel safe for the duration of the conference. We value your attendance. We expect participants to follow these rules at all workshop venues and related social events.

Conference Venue

The conference will take place at Scandic Triangeln Hotel in the heart of Malmö.
The public transport stop as well as the train station with the same name (Triangeln) are in close proximity to the hotel.

Hotel coordinates:
Address: Triangeln 2, 21143 Malmö, Sweden.
Phone: +46 40 693 47 00
Fax: +46 40 693 47 11
E-mail: triangeln@scandichotels.com.

GPS coordinates:
55°35′47.3″N 13°00′05.5″E


Holmgatan
Rönngatan
Pildammsvägen
Brogatan
Föreningsgatan
Norra Skolgatan
Torpgatan
Triangeltorget
Föreningsgatan
Scandic Triangeln
Spångatan
Spångatan
Magistratsparken
Klostergatan
Rådmansgatan
Munkgatan
Malmö Konsthall
Pildammsvägen
Friisgatan
S:t Johannesgatan
Södra Förstadsgatan
Triangeln St.
S:t Johannes kyrka
50 m

Registration

Registration will be at the conference venue, 3rd floor, on Sunday July 3 from 16:00 - 20:00. Registration will also be possible on Monday July 4 from 8:00.

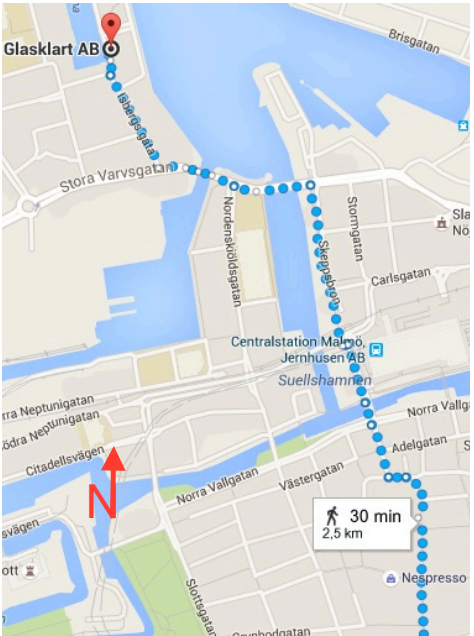
Social Events

Reception

Sunday July 3: Welcome Reception in the evening at the Workshop Hotel Scandic Hotel Triangeln, 3rd floor, from 18:00.

Conference Dinner

Thursday July 7: Conference Dinner will be hosted in the evening of Thursday, from 19:00 at the GLVSKLVRT (http://glasklart.eu/en/).
The dinner is co-hosted by Region Skåne. The venue is in the harbour area of Malmö (Dockplatsen 1, 211 19 Malmö), not far from the Central Station. If the weather is nice, it's a good half-hour walk from the Hotel (Scandic Triangeln).



4 Sponsors and Exhibitors

We would like to thank the following sponsors and exhibitors for supporting HB2016, without whose support HB2016 would not be possible.

EuCARD-2 is an Integrating Activity Project for coordinated Research and Development on Particle Accelerators, co-funded by the European Commission under the FP7 Capacities Programme. This project will contribute to positioning European accelerator infrastructures at the forefront of global research.
The project has 40 partners from 15 European countries, including Russia. The list of partners include 10 accelerator laboratories, 23 technology institutes/universities, 5 scientific research institutes and 2 industrial partners. To read more about EuCARD2 please visit: http://eucard2.web.cern.ch/.

REGION SKÅNE

Skåne region Region Skåne is the County Council of Scania County in Sweden. The county council assembly is the highest political body in the region and its members are elected by the Scanians themselves.

The regional council's main responsibility is for the public healthcare system, public transport and development within the region, which includes co-ordination of development of commerce, communication, culture and collaboration with other regions both in and outside of Sweden. To read more about Skåne region please visit: http://www.skane.se/en.

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ScandiNova

We are there when the big discoveries are made, powering the worlds most powerful particle accelerators at CERN and other leading research centers. We are there when cancer is treated, providing stable, high-precision particle beams in radiotherapy to clinics all over the world. And we are there when innovative entrepreneurs seek robust pulsed-power solutions to revolutionize industries like cargo scanning and non-destructive testing.
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Scanditronix Magnet uses experience and professional engineering know-how to design and manufacture magnets for accelerators. A recent project was the manufacture and field mapping of 80 magnet segments for MAX IV in Lund, Sweden.
Virtual Exhibitor.
http://www.scanditronix-magnet.se/

5 Author Information

Please find the plan layout in the next page.

Poster Instructions

A Poster session is scheduled for Monday afternoon. An ISO A0 sized poster (840x1188 mm) will fit standing on the board. Posters must be mounted Monday morning and must be removed at the end of the session. Mounting material will be provided.

Poster Rules

Since no contributions are accepted for publication only, any paper not presented at the conference will be excluded from the proceedings. Furthermore, the organizers reserve the right to reject publication of papers that were not properly presented in the poster session. Manuscripts of contributions to the proceedings (or large print-outs of them) are not considered as posters and papers presented in this way will not be accepted for publication. There will be a designated “poster police” to verify that posters have been displayed during the relevant poster session and posters should be manned for approximately one hour at least, allowing time for delegates to visit other posters. Papers for posters that are not displayed for the full poster session will not be published in the proceedings.

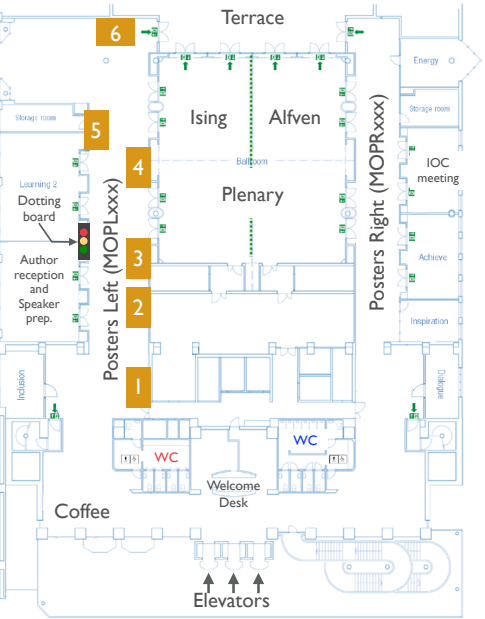
Conference Proceedings

Paper Submission

Authors will be kept updated on the status of their uploaded papers either by checking the status screen at the Workshop or by logging in to their HB2016 SPMS account. Color codes will be used to indicate the current editor status of papers. Note that, before the paper is completely ready to be published in the Proceedings, the author must have a green indication by an Editor. If the paper is being presented as a poster, it must also be additionally approved by the Poster Session Manager.

Paper acceptance

- The paper has adhered to the template and format guidance, and is ready to be published in the Proceedings.
- Changes have been made to the paper. The author must contact the proceedings office at the Conference so that the modified version can be proof-read.
- There is a major problem with the paper, such as one of the source files being corrupt. The author must contact the proceedings office to arrange to see an Editor to correct this.



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1: CPII, 2: EXIR, 3: FuG, 4: Beckhoff, 5: OECM, 6: Scandinova
Virtual Exhibitors:
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Scandic
TRANDEEM

6 List of Abstracts

7.4 Monday

Plenary Session, Monday, 2016 July 4, 9:00-12:30

MOAM1P01 **Welcome**
Mohammad Eshraqi (ESS, Lund)
Monday morning

MOAM2P20 **The LINAC4 project**

Alessandra Maria Lombardi (CERN, Geneva)

Linac4 is a normal conducting, 160 MeV H- ion accelerator that is being constructed within the scope of the LHC injectors upgrade project. Linac4 will be connected to the Proton Synchrotron Booster (PSB) during the next long LHC shut-down and it will replace the current 50 MeV hadron linac, Linac2. Linac4 is presently being commissioned, with the aim of achieving the final energy at the end of the year. A test of the injection chicane and a reliability run will follow. The beam commissioning, in steps of increasing energy, has been prepared by an extended series of studies and interlaced with phases of installation. In this paper we will detail the beam dynamics challenges and we will report on the commissioning results.

MOAM3P30 **The ESS Project**

Håkan Danared (ESS, Lund)

The European Spallation Source, ESS, is a facility for research using neutron beams that is being built in Lund. It will be the worldŠs most powerful such facility when it comes into full operation in the next decade. Neutrons will be released from a rotating tungsten target when it is hit by 2 GeV protons provided by a superconducting linac at an unprecedented 5 MW of average beam power, serving 22 neutron instruments covering a wide range of fundamental and applied sciences. An overview of the project will be given, with emphasis on technology. Current status, plans and challenges will be reviewed.

MOAM4P40 **A Fifteen Year Perspective on the Design and Performance of the SNS Accelerator**

Sarah M. Cousineau (ORNL, Oak Ridge, Tennessee)

Commissioning of the Spallation Neutron Source accelerator began approximately fifteen years ago. Since this time, the accelerator has broken new technological ground with the operation of the worldŠs first superconducting H- linac, the first liquid mercury target, and 1.4 MW of beam power. This talk will reflect on the issues and concerns that drove key decisions during the design phase, and will consider those decisions in the context of the actual performance of the accelerator. Noteworthy successes will be highlighted and lessons-learned will be discussed. Finally, a look forward toward the challenges associated with a higher power future at SNS will be presented.

MOAM5P50 **LHC Run 2: Results and Challenges**

Roderik Bruce (CERN, Geneva)

The first proton run of the LHC was very successful and resulted in important physics discoveries. It was followed by a two-year shutdown where a large number of improvements were carried out. In 2015, the LHC was restarted and this second run aims at further exploring the physics of the standard model and beyond at an increased beam energy. This talk gives a review of the main past and future challenges for the CERN accelerators to maximize the data delivered to the LHC experiments in Run II, as well as the expected LHC performance. Furthermore, the status of the 2016 LHC run and commissioning is discussed.

MOAM6P60 **Recent Progress of J-PARC MR Beam Commissioning and Operation**

Susumu Igarashi (KEK, Ibaraki)

The main ring (MR) of the Japan Proton Accelerator Research Complex (J-PARC) has been providing 30-GeV proton beams for elementary particle and nuclear physics experiments since 2009. The beam power of 390 kW has been recently achieved with 2e14 protons per pulse and the cycle time of 2.48 s for the neutrino oscillation experiment. Main efforts in the beam tuning are to minimize beam losses and to localize the losses at the collimator section. Recent improvements include the 2nd harmonic rf operation to reduce the space charge effect with a larger bunching factor and corrections of resonances near the operation setting of the betatron tune. Because the beam bunches were longer with the 2nd harmonic rf operation, the injection kicker system was improved to accommodate the long bunches. We plan to achieve the target beam power of 750 kW in 2018 by making the cycle time faster to 1.3 s with new power supplies of main magnets, rf upgrade and improvement of injection and extraction devices. The possibility of the beam power beyond 750 kW is being explored with new settings of the betatron tune.

MOAM7P70 **Fermilab PIP-II Status and Strategy**

Shekhar Mishra, Paul Derwent, Stephen Holmes, Valeri Lebedev, Donald Mitchell (Fermilab, Batavia, Illinois)

Proton Improvement Plan-II (PIP-II) is the centerpiece of FermilabŠs plan for upgrading the accelerator complex to establish the leading facility in the world for particle physics research based on intense proton beams. PIP-II has been developed to provide 1.2 MW of proton beam power at the start of operations of the Long Baseline Neutrino Experiment (LBNE), while simultaneously providing a platform for eventual extension of LBNE beam power to >2 MW and enabling future initiatives in rare processes research based on high duty factor/higher beam power operations. PIP-II is based on the construction of a new, 800 MeV, superconducting linac, augmented by improvements to the existing Booster, Recycler, and Main Injector complex. PIP-II is currently in the development stage with an R&D program underway targeting the front end and superconducting rf acceleration technologies. This paper will describe the status of the PIP-II conceptual development, the associated technology R&D programs, and the strategy for project implementation.

MOPM1P80 **Accelerator Physics Challenges in FRIB Driver Linac**

Masanori Ikegami (FRIB, East Lansing, Michigan)

FRIB is a heavy ion linac facility to accelerate all stable ions to the energy of 200 MeV/u with the beam power of 400 kW, which is under construction at Michigan State University in USA. FRIB driver linac is a beam power frontier accelerator aiming to realize two orders of magnitude higher beam power than existing facilities. It consists of more than 300 low-beta superconducting cavities with unique folded layout to fit into the existing campus with innovative features including multi charge state acceleration. In this talk, we overview accelerator physics challenges in FRIB driver linac with highlight on recent progresses and activities preparing for the coming beam commissioning.

MOPM2P90 **Status and Challenges of High Intensity Heavy Ion Accelerator Facility (HIAF) in China**

Jiancheng Yang, Jia Wen Xia, Guo Qing Xiao, Hushan Xu, Youjin Yuan, Hongwei Zhao, Xiaohong Zhou (IMP/CAS, Lanzhou)

HIAF is a proposed new accelerator facility in China. The facility is being designed to provide intense primary and radioactive beams for a wide range of research fields. The HIAF facility plan was approved by central government of China in December 2015. The machine studies are now mainly focused on design optimization and key technical R&D.The unique features of the first phase of HIAF are high current pulsed beams from iLinac and high intensity heavy ion beams with ultra-short bunch length from BRing. The cooled rare isotope beams also will be prepared through projectile-fragmentation (PF) method and advanced beam cooling technology. To reach the main goals of the HIAF facility, there are still several technical challenges such as operation with high intensity beams, control of the dynamic vacuum pressure, beam compression for very short pulse beam and the design of Nuclotron-type superconducting magnets. For most of those challenges solutions have been found and prototypes are being built through close international collaborations. The general description, accelerator challenges and present status are given in the presentation.

MOPM3P01 **Beam Optics Simulations of the Pre-Stripper Linac for Rare Isotope Science Project**

Jong-Won Kim, Ji-Ho Jang, Hyunchang Jin (IBS, Daejeon), Zachary Alan Conway, Brahim Mustapha, Peter Ostroumov (ANL, Argonne, Illinois)

The rare isotope science project (RISP) under development in Korea aims to provide various heavy-ion beams for nuclear and applied science users. A pre-stripper linac is the first superconducting section to be constructed for the acceleration of both stable and radioisotope beams to the energy of 18.5 Mev/u with a DC equivalent voltage of 160 MV. The current baseline design consists of an ECR ion source, an RFQ, cryomodules with QWR and HWR cavities and quadruple focusing magnets in the warm sections between cryomodules. Recently we have developed an alternative design in collaboration with ArgonneÀs Linac Development Group to layout the linac based on state-of-the-art ANLÀs QWR operating at 81.25 MHz and multi-cavity cryomodules of the type used for the ATLAS upgrade and Fermilab PIP-II projects. End-to-end beam dynamics calculations have been performed to ensure an optimized design with no beam losses. The numbers of required cavities and cryomodules are significantly reduced in the alternative design. The results of beam optics simulations and error sensitivity studies are discussed.

MOPM4P01 **Challenges and Performance of the C-ADS Injector System**

Yunlong Chi (IHEP, Beijing)

Along with the rapid development of nuclear power plants in China, treatment of the nuclear waste has become a crucial issue. Supported by the "Strategic Priority Research Program" of the Chinese Academy of Sciences (CAS), The Chinese ADS project is now on-going based on the collaboration of several Chinese institutions. In the end of year 2015, China Initiative ADS (CIADS) program is approved by Chinese government, will construct in the Guangdong province south part of China. The proton accelerator of Chinese ADS is a superconducting CW linear accelerator. Its energy is 1.5GeV, with beam current of 10mA. Institute of High Energy Physics (IHEP) and Institute of Modern Physics (IMP) are responsible to developing this superconducting CW linear accelerator. In the injector part there are many challenges to developing several different low beta superconducting cavities and related hardwares such like LLRF system etc. In this paper presents the progress of two different injector development including SC cavities and related hardwareŠs and performance test of two injectors and key hardwareŠs, and also brief introduction of CIADS program.

MOPR001 **Figure-8 Storage Ring Ű Investigation of the Scaled Down Injection System**

Heiko Niebuhr, Adem Ates, Martin Droba, Oliver Meusel, Daniel Noll, Ulrich Ratzinger, Joschka Felix Wagner (IAP, Frankfurt am Main)

To store high current ion beams up to 10 A, a superconducting storage ring (F8SR) is planned at Frankfurt university. For the realisation, a scaled down experimental setup with normalconducting magnets is being build. Investigations of beam transport in solenoidal and toroidal guiding fields are in progress. At the moment, a new kind of injection system consisting of a solenoidal injection coil and a special vacuum vessel is under development. It is used to inject a hydrogen beam sideways between two toroidal magnets. In parallel operation, a second hydrogen beam is transported through both magnets to represent the circulating beam. In a second stage, an ExB-Kicker will be used as a septum to combine both beams into one. The current status of the experimental setup will be shown. For the design of the experiments, computer simulations using the 3D simulation code bender were performed. Different input parameters were checked to find the optimal injection and transport channel for the experiment. The results will be presented.

MOPR002 **Study of the magnet measurements during the injection region for CSNS/RCS**

Ming-Yang Huang, Nan Huang, Lihua Huo, Hongfei Ji, Wen Kang, Yiqin Liu, Jun Peng, Jing Qiu, Li Shen, Sheng Wang, Shou Yan Xu, Jing Zhang (IHEP, Beijing)

A combination of the H- stripping and phase space painting method is used to accumulate a high intensity beam in the Rapid Cycling Synchrotron (RCS) of the China Spallation Neutron Source (CSNS). The injection system for CSNS/RCS consists of three kinds of magnets: four direct current magnets BC1-BC4, eight alternating current magnets BH1-BH4 and BV1-BV4, two septum magnets ISEP1 and ISEP2. In this paper, the magnet measurements of these magnets were introduced and the data analysis was processed. The magnetizing curves of these magnets were given and the magnetizing fitting equations were obtained.

MOPR003 **HOM Analysis of A HWR Cavity for 100 mA Proton Acceleration**

Feng Zhu, Peiliang Fan, Kexin Liu, Shengwen Quan, Hutianxiang Zhong (PKU, Beijing)

There's presently a growing demand for cw high current proton and deuteron linear accelerators based on superconducting technology to better support various fields of science. Up to now, high order modes (HOMs) studies induced by ion beams with current higher than 10mA and even 100 mA accelerated by low β non-elliptical Superconducting rf (SRF) cavity are very few. Two main HOM related issues of the SRF linac are the beam instabilities and the HOM-induced power. In this paper, we compare the HOM power induced by 100mA beam of a β=0.09 HWR SRF cavity calculated from time domain solver and frequency domain cavity eigenmodes spectrum method. The effect of the HOMs to the beam emittance is also presented.

MOPR004 **H- Charge Exchange Injection for XiPAF Synchrotron**

Hongjuan Yao, Xialing Guan, Guangrui Li, Xuewu Wang, Qingzi Xing, Shu-xin Zheng (TUB, Beijing)

The physics design of the H- charge exchange injection system for Xian Proton Application Facility (XiPAF) synchrotron with the missing dipole lattice is discussed. The injection scheme is composed of one septum magnet, three chicane dipoles, two bump magnets and one carbon stripping foil. A 5μg/cm2 carbon foil is chosen for 7MeV H- beam for high stripping efficiency and low coulomb scattering effect. The simulation results of the horizontal and vertical phase space painting finished by two bumper magnets and mismatching respectively are presented.

MOPR005 **RF-Knockout Slow Extraction Design for XiPAF Synchrotron**

Hongjuan Yao, Xialing Guan, Guangrui Li, Xuewu Wang, Qi Zhang, Shu-xin Zheng (TUB, Beijing)

The physics design of slow extraction for Xian Proton Application Facility (XiPAF) synchrotron is discussed. The extraction scheme is composed of two resonant sextupoles, one electrostatic septum (ES) and two septum magnets. The phase space diagram under the Hardt condition at the entrance of ES and the last three turns trajectory before extraction are presented. A program is written with C++ to simulate slow extraction process by RF-knockout (RF-KO), the calculation results of dual frequency modulation (FM) and amplitude modulation (AM) are given, and the standard deviation of the fluctuation parameter R1 can be limited 0.2 with optimum parameters under a sampling frequency of 10 kHz.

MOPR006 **Design of the 230MeV Proton Accelerator for Xian Proton Application Facility**

Hongjuan Yao, Huaibi Chen, Cheng Cheng, Changtong Du, Lei Du, Taibin Du, Xialing Guan, Wenhui Huang, Hongping Jiang, Guangrui Li, Chuanxiang Tang, Ruo Tang, Dan wang, Minwen Wang, Xuewu Wang, Lin Wu, Qingzi Xing, Ye Yang, Zheng Yang, hong-jin zeng, Huayi Zhang, Qi Zhang, Qingzhu Zhang, Shu-xin Zheng (TUB, Beijing), Mengtong Qiu, Baichuan Wang, Yan-Ping wang, Zhongming Wang, Yi-Hua Yan, Hui Zhang, Chen Zhao (State Key Laboratory of Intense Pulsed Radiation Simulation and Effect, Shannxi)

A design result of the 230 MeV proton accelerator for Xi'an Proton Application Facility (XiPAF) is presented. XiPAF was newly designed to be located in Xian city and provide the proton beam with the maximum energy of 230 MeV for the research of the single event effect. The facility is mainly composed of a 230 MeV six-fold synchrotron with a 7 MeV H- linac injector and two experimental stations. A flux of 105 108 p/cm2/s with the uniformity of better than 90% on the sample in the range of 1 cm$\times$1 cm 10 cm$\times$10 cm is designed.

MOPR007 **Cool and High Power Test of Large Size Magnetic Alloy Core for Xi-paf's Synchrotron**

Guangrui Li, Xialing Guan, Xuewu Wang, Zheng Yang, Hongjuan Yao, hong-jin zeng, Shu-xin Zheng (TUB, Beijing)

A compact magnetic alloy (MA) loaded cavity is under development for XiPAF's synchrotron. The cavity contains 6 large size MA cores, each is independently coupled with solid state power amplifier. Two types of MA core are proposed for the project. We have developed a single core model cavity to verify the impedance model and to test the properties of MA cores under high power state. The high power test results are presented and discussed.

MOPR008 **Dynamic vacuum simulation in the CSRm**

Peng Li, Zhen Chai, Cheng Luo, Ruishi Mao, Jun Meng, Jiachen Wang, Jiancheng Yang, Youjin Yuan, Wenheng Zheng (IMP/CAS, Lanzhou)

HIRFL-CSR is an ion cooler-storage-ring facility in China's Institute of Modern Physics (IMP). The beams are accumulated, electron cooled, accelerated and extracted from the main Cooler-Storage-Ring (CSRm) to different terminals. The heavy ion beams are easily lost at the vacuum chamber along the CSRm when it is used to accumulate intermediate charge state particles. The vacuum pressure bump due to the ion-induced desorption in turn leads to an increase in beam loss rate. In order to accumulate the beams to higher intensity to fulfill the requirements of physics experiments and for better understanding of the dynamic vacuum pressure caused by the beam loss, dynamic vacuum pressure evolution along the CSRm has been calculated and measured during the accelerator operation. The beam loss distribution is simulated considering the particle charge exchanged process firstly. Then the dynamic vacuum pressure calculation method which developed from the VAKDYN is introduced in this paper. The vacuum pressure evolution along the CSRm has been recorded though a new LabVIEW code. This paper compared the simulation and the measurement result of the vacuum pressure in the CSRm.

MOPR009 **Transverse Beam Splitting Made Operational: Recent Progress of the Multi-Turn Extraction at the CERN Proton Synchrotron**

Alexander Huschauer, Jan Borburgh, Sanja Damjanovic, Simone Silvano Gilardoni, Massimo Giovannozzi, Michael Hourican, Karsten Kahle, Gilles Le Godec, Olivier Michels, Guido Sterbini (CERN, Geneva), Cédric Hernalsteens (EPFL, Lausanne)

Following a successful commissioning period, the Multi-Turn Extraction (MTE) at the CERN Proton Synchrotron (PS) has been applied for the fixed-target physics programme at the Super Proton Synchrotron (SPS) since September 2015. This exceptional extraction technique was proposed to replace the long-serving Continuous Transfer (CT) extraction, which has the drawback of inducing high activation of the ring. MTE exploits the principles of non-linear beam dynamics to perform loss-free beam splitting in the horizontal phase space. Over multiple turns, the resulting beamlets are then transferred to the downstream accelerator. The operational deployment of MTE was rendered possible by the full understanding and mitigation of different hardware limitations and by redesigning the extraction trajectories and non-linear optics, which was required due to the installation of a dummy septum to reduce the activation of the magnetic extraction septum. The results of the related experimental and simulation studies, a summary of the 2015 performance analysis, as well as more recent performance improvements are presented in this paper.

MOPR010 **Machine Element Contribution to the Longitudinal Impedance Model of the CERN SPS**

Thomas Kaltenbacher, Fritz Caspers, Christine Vollinger (CERN, Geneva)

This contribution describes new contributions to the current longitudinal impedan model of the SPS and studies carried out in order to improve, extend and update it. Specifically, new sources of impedances have been identified, evaluated and included in the model. One finding are low Q and low-frequency (below 1 GHz) resonances which occur due to enamelled flanges in combination with external cabling e.g. ground loops. These resonances couple to the beam through the gap with enamel coating which creates an open resonator. Since this impedance is important for beam stability in the CERN Proton Synchrotron (PS), RF by-passes were installed on the enamelled flanges, and their significance for the SPS beam is currently under investigation. Simulations, bench and beam measurements were used to deduce model parameters for beam dynamic simulations.

MOPR011 **The SPS 200 MHz TWC Impedance after the LIU Upgrade**

Toon Roggen, Rama Calaga, Fritz Caspers, Thomas Kaltenbacher, Christine Vollinger (CERN, Geneva)

As a part of the Large Hadron Collider (LHC) Injectors Upgrade project (LIU) the 200 MHz Travelling Wave Cavities (TWC) of the Super Proton Synchrotron (SPS) will be upgraded. The two existing 5-section cavities will be rearranged into four 3-section cavities, thereby increasing the total voltage from 7 MV (I_{RF} = 1.5 A) to 10 MV (I_{RF} = 3.0 A). Projections of the High Luminosity-LHC era are conceived by the macro-particle simulation code BLonD, that makes use of an impedance model of the SPS which is developed from a thorough survey of individual machine elements. This paper will analyze the impedance contribution of the 200 MHz cavities in the two configurations, using electromagnetic simulation codes. In addition RF-measurements carried out on the existing cavities in the SPS as well as on a single section prototype are presented.

MOPR012 **The New HL-LHC Injection and Transport Protection System**

Francesco Maria Velotti, Wolfgang Bartmann, Chiara Bracco, Matthew Alexander Fraser, Brennan Goddard, Verena Kain, Anton Lechner, Malika Meddahi (CERN, Geneva)

The High-Luminosity LHC (HL-LHC) upgrade represents a challenge for the full chain of its injectors. The aim is to provide beams with a brightness a factor of two higher than the present maximum achieved. The 450 GeV beams injected into the LHC are directly provided by the Super Proton Synchrotron (SPS) via two transfer lines (TL), TI2 and TI8. Such transfer lines are both equipped with a passive protection system to protect the LHC aperture against ultra-fast failures of the extraction and transport systems. In the LHC instead, the injection protection system protects the cold apertures against possible failures of the injection kicker, MKI. Due to the increase of the beam brightness, these passive systems need to be upgraded. In this paper, the foreseen and ongoing modifications of the LHC injection protection system and the TL collimators are presented. Simulations of the protection guaranteed by the new systems in case of failures are described, together with benchmark with measurements for the current systems.

MOPR013 **Analysis and Robust Design of Feedback Systems for Controlling Intra-bunch Instabilities at the SPS (CERN)**

Claudio Hector Rivetta, John Fox, Ozhan Turgut (SLAC, Menlo Park, California), Wolfgang Höfle, Kevin Shing Bruce Li (CERN, Geneva)

Different feedback strategies for controlling intra-bunch instabilities driven by electron-clouds or strong head-tail coupling (transverse mode coupled instabilities TMCI) have been analyzed and presented using classical and model-based design control techniques [1]-[3]. The different controllers proposed have advantages and limitations. In this paper, different control techniques are compared taking into account realistic limitations in the system such as bandwidth, nonlinearities in the hardware and maximum power deliverable. Robustness of the system is evaluated as a function of parameter variations and different operation conditions of the CERN-SPS machine. Designs are evaluated using multi-particle simulation codes (CMAD / HeadTail) and compared to trade-off system performance and hardware complexity. Results of recent measurements in the SPS ring, where unstable beams are controlled are reported and compared with the simulation studies.

MOPR014 **Corrector Magnets for the Cbeta and eRHIC Projects and Hadron Facilities***

Nicholaos Tsoupas, Stephen Brooks, Yue Hao, Animesh Kumar Jain, George Mahler, Francois Meot, Vadim Ptitsyn, Dejan Trbojevic (BNL, Upton, Long Island, New York)

The Cbeta project[1] is a prototype electron accelerator for the proposed eRHIC project[2]. The electron accelerator is based on the Energy Recovery Linac (ERL) and the Fixed Field Alternating Gradient (FFAG) principles. The FFAG arcs of the accelerator are comprised of one focusing and one defocusing quadrupoles which are designed as Halbach-type permanent magnet quadrupoles[3]. We propose window frame electro-magnets surrounding the Halbach magnets to be used as normal and skew dipoles correctors and quadrupol correctors. We will present results from OPERA-3D calculations of the effect of these corrector magnets on the magnetic field of the main quadrupole magnets and the results will be compared with experimental measurements. We will also discuss applications of permanent magnets with such correctors for hadron beam facilities.

MOPR015 **Beta-beating Estimates and Corrections at SIS100**

Vera Chetvertkova, Oliver Boine-Frankenheim, Youssef El Hayek, Giuliano Franchetti, David Ondreka, Rahul Singh, Kei Sugita (GSI, Darmstadt)

Linear magnet errors cause modifications of accelerator optics. This effect is unwanted and requires proper correction. By using Mad-X we estimate the beta-beating for SIS100, taking into account also the misalignment of the sextupole magnets. The influence of the quadrupole errors on the beta function is discussed and the correction strategy is presented. In view of assessing the effect of space charge we present the dependence of beta-beating on the working point, and discuss the consequences for the correction strategy.

MOPR016 **Mitigation of Numerical Noise for Beam Loss Simulations**

Frederik Kesting (IAP, Frankfurt am Main), Giuliano Franchetti (GSI, Darmstadt)

Numerical noise emerges in self-consistent simulations of charged particles, and its mitigation is investigated since the first numerical studies in plasma physics. In accelerator physics, recent studies find an artificial diffusion of the particle beam due to numerical noise in particle-in-cell tracking, which is of particular importance for high intensity machines with a long storage time, as the SIS100 at FAIR or in context of the LIU upgrade at CERN. In order to draw conclusions from beam loss simulations for these projects, artificial effects must be distinguished from physical beam loss. Therefore, it is important to relate artificial diffusion to artificial beam loss, and to choose simulation parameters such that physical beam loss is well resolved. As a practical tool, we therefore suggest a scaling law to find optimal simulation parameters for a given maximum percentage of acceptable artificial beam loss.

MOPR017 **Status of the Beam Instrumentation System of CSNS**

Jilei Sun, Jun Peng (CSNS, Guangdong Province), Taoguang Xu (IHEP, Beijing)

The first section DTL commissioning of China Spallation Neutron Source (CSNS) project has been successful finished in January, 2016. The H- beam can be accelerated to 21.6 MeV at peak current 18 mA, achieved the design point. Different elements of the beam instrumentation system have been tested during the commissioning, including BPM, CT, FCT, WS, EM, BLM, and corresponding electronics and control systems. High accuracy phase measurement (precision @ $\pm$1ą) system has been started into operation. Beam loss monitor (BLM) for low energy, 3 MeV to 21.6 MeV, has been tested too, and got very positive results. For the LRBT, RCS and RTBT, different type wire scanner, BPM, WCM, CT were designed. The monitors fit for the high-radiation environments were considered. All the physical design work has been finished, and being manufactured. Lab test will be started in June and the LINAC commissioning (beam energy up to 80 MeV) will be started in August.

Commissioning and Operations, Monday, 2016 July 4, 16:00-18:00

MOPR018 **XAL APPLICATIONS DEVELOPMENT FOR CSNS TRANSPORT LINES**

Yong Li, Zhiping Li, Weibin Liu (IHEP, Beijing), Jun Peng (CSNS, Guangdong Province)

XAL is an application programming framework initially developed at the Spallation Neutron Source (SNS). It has been employed as a part of control system via con-nection to EPICS to provide application programs for beam commissioning at the China Spallation Neutron Source (CSNS). Several XAL-based applications have been developed for Beam Transport line at CSNS and successfully applied in the MEBT and DTL-1 beam commissioning. These applications will be discussed in this paper.

MOPR020 **SPACE CHARGE EFFECTS OF HIGH INTENSITY BEAMS AT BRING**

Jie Li (IMP/CAS, Lanzhou)

Space charge effects perform one of the main intensity limitations for low energy synchrotron. Large tune spread and crossing resonance stop-bands can hardly be avoided for intensive heavy ion beam at high intensity. Several subjects like the tune spread, beam emittance change, and structure resonance are studied. Simulations are carried out focusing on the best suitable working point at injection energy and acceptable beam intensity for the booster ring of the High Intensity heavy ion Accelerator Facility (HIAF).

MOPR021 **Overview of the ESSnuSB Accumulator Ring**

Maja Olvegaard, Tord Ekelöf (Uppsala University, Uppsala), Elena Benedetto, Magdalena Cieslak-Kowalska, Michel Martini, Horst Schönauer, Elena Wildner (CERN, Geneva)

The European Spallation Source (ESS) is a research center based on the worldŠs most powerful proton driver, 2.0 GeV, 5 MW on target, currently under construction in Lund. With an increased pulse frequency, the ESS linac could deliver additional beam pulses to a neutrino target, thus giving an excellent opportunity to produce a high-performance ESS neutrino Super-Beam (ESSnuSB). The focusing system surrounding the neutrino target requires short proton pulses. An accumulator ring and acceleration of an H- beam in the linac for charge-exchange injection into the accumulator could provide such short pulses. In this paper we present an overview of the work with optimizing the accumulator design and the challenges of injecting and storing 1.1E15 protons per pulse from the linac. In particular, particle tracking simulations with space charge will be described in this paper.

MOPR022 **Longitudinal Particle Tracking Code for a High Intensity Proton Synchrotron**

Masanobu Yamamoto (JAEA/J-PARC, Tokai-Mura, Naka-Gun, Ibaraki-Ken)

We have been developing a longitudinal particle tracking code to design and investigate the beam behavior of the J-PARC proton synchrotrons. The code calculate the longitudinal particle motion with a wake voltage and a space charge effect. The most different point from the other codes is that a synchronous particle motion is calculated from the bending magnetic field pattern. This means the synchronous particle is independent from an acceleration frequency pattern. This feature is useful to check the adiabaticity of the synchrotron. The code also calculates the longitudinal emittance and the filling factor at an rf bucket under the multi-harmonics. Furthermore, a vacuum tube operation analysis can be included into the code. We can estimate a power supply current for the tube amplifier and an unwanted voltage distortion at an rf cavity. We will describe the feature of the code.

MOPR023 **Interpretation of Wire-Scanner Asymmetric Profiles in a Low-Energy Ring**

Elena Benedetto, Magdalena Cieslak-Kowalska (CERN, Geneva)

In the CERN PS Booster, wire-scanner profile measurements performed at injection energy are affected by a strong asymmetry. The shape was reproduced with the code pyOrbit, assuming that the effect is due to the beam evolution during the scans, under the influence of space-charge forces and Multiple Coulomb Scattering at the wire itself. Reproducing the transverse profiles during beam evolution allows to use them reliably as input for simulation benchmarking.

MOPR024 **General Formula to Deduce the Space Charge Tune Spread From a Quadrupolar Pick-Up Measurement**

Elias Métral (CERN, Geneva)

In 1966, W. Hardt derived the oscillation frequencies obtained in the presence of space charge forces and gradients errors for elliptical beams. Since then, a simple formula is usually used to relate the shift of the quadrupolar mode (obtained from the quadrupolar pick-up) and the space charge tune spread, depending only on the ratio between the two transverse equilibrium beam sizes. However, this formula is not always valid, in particular for machines running close to the coupling resonance Qx = Qy with almost round beams. A new general formula is presented, giving the space charge tune spread as a function of i) the measured shift of the quadrupolar mode, ii) the ratio between the two transverse equilibrium beam sizes and iii) the distance between the two transverse tunes.

MOPR025 **Space Charge Modules for PyHEADTAIL**

Adrian Oeftiger (CERN, Geneva), Stefan Hegglin (ETH, Zurich)

PyHEADTAIL is a 6D tracking tool developed at CERN to simulate collective effects. We present recent developments of the direct space charge suite, which is available for both the CPU and GPU. A new 3D particle-in-cell solver with open boundary conditions has been implemented. For the transverse plane, there is a semi-analytical Bassetti-Erskine model as well as 2D self-consistent particle-in-cell solvers with both open and closed boundary conditions. For the longitudinal plane, PyHEADTAIL offers line density derivative models. Simulations with these models are benchmarked with experiments at the injection plateau of CERN's Super Proton Synchrotron.

MOPR026 **Space Charge Mitigation With Longitudinally Hollow Bunches**

Adrian Oeftiger, Steven Hancock, Giovanni Rumolo (CERN, Geneva)

Hollow longitudinal phase space distributions have a flat profile and hence reduce the impact of transverse space charge. Dipolar parametric excitation with the phase loop feedback systems provides such hollow distributions under reproducible conditions. We present a procedure to create hollow bunches during the acceleration ramp of CERN's PS Booster machine with minimal changes to the operational cycle. The improvements during the injection plateau of the downstream Proton Synchrotron are assessed in comparison to standard parabolic bunches.

MOPR027 **Dynamic Beta and Beta-Beating Effects in the Presence of the Beam-Beam Interactions**

Tatiana Pieloni, Xavier Buffat, Rogelio Tomas (CERN, Geneva)

The Large Hadron Collider (LHC) has achieved correction of beta beat down to better than 5%. The beam-beam interactions at the four experiments result as extra quadrupole error in the lattice. This will produce a change of the beta* at the experiments and a beating along the arcs which for the HL-LHC will be very large. Estimations of these effects will be given for the LHC and HL-LHC cases.

MOPR028 **CERN PS Booster Longitudinal Dynamics Simulations for the Post-LS2 Scenario**

Danilo Quartullo, Simon Christopher Paul Albright, Elena Shaposhnikova (CERN, Geneva)

The CERN PS Booster is the first synchrotron in the LHC proton injection chain; it currently accelerates particles from 50 MeV to 1.4 GeV kinetic energy. However several upgrades foreseen by the LHC Injectors Upgrade Program will allow the beam to be accelerated from 160 MeV to 2 GeV after the Long Shutdown 2 in 2021. The present RF system will be replaced by the new one, based on Finemet technology. These and other improvements will help to increase the LHC luminosity by factor ten. In order to study beam stability in the longitudinal plane, simulations have been performed with the CERN BLonD code using an accurate longitudinal impedance model and a reliable estimation of the longitudinal space charge. Particular attention has been dedicated to the three main features that currently let the beam go stable through the ramp: double RF operation in bunch-lengthening mode to reduce the transverse space charge tune spread, exploitation of feedback loops to damp dipole oscillations and controlled longitudinal emittance blow-up. The RF phase noise injection has been considered to study if it could complement or substitute the currently used method based on phase modulation.

MOPR029 **On the Impact of Non-Symplecticity of Space Charge Solvers**

Malte Titze (CERN, Geneva)

To guarantee long-term reliability in the predictions of a numerical integrator, it is a well-known requirement that the underlying map has to be symplectic. It is therefore important to examine in detail the impact on emittance growth and noise generation in case this condition is violated. We present a strategy of how to tackle this question and some results obtained for particular PIC and frozen space charge models.

MOPR030 **Simple Models for Beam Loss Near the Half Integer Resonance with Space Charge**

Christopher Warsop, Dean Adams, Bryan Jones, Ben Graeme Pine (STFC/RAL/ISIS Chilton, Didcot, Oxon)

The half integer resonance is often used to define the high intensity limit of medium or low energy hadron rings where transverse space charge is significant. However, the mechanism leading to particle loss as beam approaches this resonance, which thus defines the limit, is not clearly understood. In this paper we explore simple models, based on single particle resonance ideas, to see if they describe useful aspects of motion as observed in simulations and experiments of 2D coasting beams on the ISIS synchrotron. Single particle behaviour is compared to 2D self-consistent models to assess when coherent motion begins to affect the single particle motion, and understand the relevance of coherent and incoherent resonance. Whilst the general problem of 2D resonant loss, with non-stationary distributions and non-linear fields is potentially extremely complicated, here we suggest that for a well-designed machine, where higher order pathological loss effects are avoided, a relatively simple model may give valuable insights into beam behaviour and control.

MOPR031 **Development of Physics Models of the ISIS Head-Tail Instability**

Robert Williamson, Bryan Jones, Christopher Warsop (STFC/RAL/ISIS, Chilton, Didcot, Oxon)

ISIS is the pulsed spallation neutron and muon source at the Rutherford Appleton Laboratory in the UK. Operation centres on a rapid cycling proton synchrotron which accelerates 3E13 protons per pulse (ppp) from 70 MeV to 800 MeV at 50 Hz, delivering a mean beam power of 0.2 MW. As a high intensity, loss-limited machine, research and development at ISIS is focused on understanding loss mechanisms with a view to increasing operational intensity and pinpointing possible upgrade routes. The head-tail instability observed on ISIS is of particular interest as it is currently the main limitation on beam intensity. This paper presents developments of a new, in-house code to simulate the head-tail instability observed including benchmarks against theory and comparisons with experimental results. Recent beam-based measurements of the effective transverse impedance of the ISIS Synchrotron will also be presented.

MOPR033 **Beam Acceleration and Transition Crossing in the Fermilab Booster**

Valeri Lebedev, Chandra Bhat, Jean-Francois Ostiguy (Fermilab, Batavia, Illinois)

To suppress eddy currents, the Fermilab rapid cycling Booster synchrotron has no beam pipe; rather, its combined function dipoles are evacuated, exposing the beam directly to the magnet laminations. This arrangement significantly increases the resistive wall impedance of the dipoles and, in combination with the space charge impedance, substantially complicates longitudinal dynamics at transition. Voltage and accelerating phase profiles in the vicinity of transition are typically empirically optimized to minimize beam loss and emittance growth. In this contribution, we present results of experimental studies of beam acceleration near transition. Using comparisons between observed beam parameters and simulations, we obtain accurate calibrations for the RF program and extract quantitative information about parameters of relevance to the Booster laminated magnets longitudinal impedance model. The results are used to analyze transition crossing in the context of a future 50% increase in beam intensity planned for PIP-II, an upgrade of the Fermilab accelerating complex.

MOPR034 **Suppression of Half-Integer Resonance in Fermilab Booster**

Valeri Lebedev, Alexander Valishev (Fermilab, Batavia, Illinois)

The particle losses at injection in the FNAL Booster are one of the major factors limiting the machine performance. The losses are caused by motion nonlinearity due to direct space charge and due to non-linearity introduced by large values of chromaticity sextupoles required to suppress transverse instabilities. The report aims to address the former - the suppression of incoherent space charge effects by reducing deviations from the perfect periodicity of linear optics functions. It should be achieved by high accuracy optics measurements with subsequent optics correction and by removing known sources of optics perturbations. The study shows significant impact of optics correction on the half-integer stop band with subsequent reduction of particle loss. We use realistic Booster lattice model to understand the present limitations, and investigate the possible improvements which would allow high intensity operation with PIP-II parameters.

MOPR035 **Electron Lens for the Fermilab Integrable Optics Test Accelerator**

Giulio Stancari (Fermilab, Batavia, Illinois)

The Integrable Optics Test Accelerator (IOTA) is a research machine currently being designed and built at Fermilab. The research program includes the study of nonlinear integrable lattices, beam dynamics with self fields, and optical stochastic cooling. One section of the ring will contain an electron lens, a low-energy magnetized electron beam overlapping with the circulating beam. The electron lens can work as a nonlinear element, as an electron cooler, or as a space-charge compensator. We describe the physical principles, experiment design, and hardware implementation plans for the IOTA electron lens.

MOPR036 **Spin Tracking of Polarized Protons in the Main Injector at Fermilab**

Meiqin Xiao (Fermilab, Batavia, Illinois), Callum Aldred, Wolfgang Lorenzon (Michigan University, Ann Arbor, Michigan)

The Main Injector (MI) at Fermilab currently produces high-intensity beams of protons at energies of 120 GeV for a variety of physics experiments. Acceleration of polarized protons in the MI would provide opportunities for a rich spin physics program at Fermilab. To achieve polarized proton beams in the Fermilab accelerator com-plex, shown in Fig.1.1, detailed spin tracking simulations with realistic parameters based on the existing facility are required. This report presents studies at the MI using a single 4-twist Siberian snake to determine the depolariz-ing spin resonances for the relevant synchrotrons. Results will be presented first for a perfect MI lattice, followed by a lattice that includes the real MI imperfections, such as the measured magnet field errors and quadrupole misa-lignments. The tolerances of each of these factors in maintaining polarization in the Main Injector will be discussed.

MOPR037 **Space Charge Effects on Ion Beam Dynamics and Integrability in the Iota Ring**

Nathan M. Cook, David Leslie Bruhwiler, Christopher Hall, Rami Alfred Kishek, Stephen Davis Webb (RadiaSoft LLC, Boulder, Colorado), Alexander Leonidovich Romanov, Alexander Valishev (Fermilab, Batavia, Illinois)

Modern hadron accelerators such as spallation sources and neutrino factories must push the intensity limits to meet increasingly challenging demands on performance.ÊThe Integrable Optics Test Accelerator (IOTA) is a small ring, currently under construction at Fermilab, which will explore advanced concepts in beam dynamics with low-energy proton beams with high space charge tune depression. Through use of a special nonlinear magnet insertion, large tune spread with amplitude can be achieved while preserving two integrals of motion for the single particle behavior. The stability of these invariants is particularly sensitive to collective effects such as space charge induced tune depression. We present results from simulations of IOTA using the particle-in-cell framework Warp and the accelerator simulation package Synergia exploring the behavior of proton beams in the presence of space charge. We examine potential lattice variations that correct for tune depression and beam mismatch while minimizing deviations from integrability.

MOPR038 **Nonlinear Dynamics and Paths to Integrability in the IOTA Lattice**

Nathan M. Cook, David Leslie Bruhwiler, Christopher Hall, Rami Alfred Kishek, Stephen Davis Webb (RadiaSoft LLC, Boulder, Colorado), Alexander Leonidovich Romanov, Alexander Valishev (Fermilab, Batavia, Illinois)

Betatron tune spread with amplitude suppresses intensity-driven parametric instabilities such as beam halo. Conventional approaches, such as using octupoles, can reduce the single-particle dynamic aperture. The concept of nonlinear integrable optics promises to introduce order unity tune spreads without introducing nonlinear resonances that limit the dynamic aperture.ÊThe idealized zero-current dynamics is constrained by two integrals of the motion, but even the single particle motion can be perturbed by energy spread. To study this concept, Fermilab is building the Integrable Optics Test Accelerator (IOTA). Simulations using the accelerator simulation package Synergia have demonstrated higher order effects to the ideal lattice, including effects due to finite phase advance across the nonlinear magnet and a particular sensitivity to chromaticity-correcting schemes. We present evidence for these higher-order effects, andÊillustrate the sensitivity of the dynamics to sextupole fields, showing that their proper pairing can preserve integrability and reduce beam loss.

MOPR039 **Survey of Variational Algorithms for Modeling Intense Beams**

Stephen Davis Webb (RadiaSoft LLC, Boulder, Colorado)

Variational algorithms are a promising tool recently rediscovered and being applied to plasma-based accelerators, fusion plasmas, and intense beams. We offer a brief historical survey of the subject, and describe the foundational concepts of the algorithm. We then present their application to the problems of beam loading in RF cavities and space charge. By making careful choices in constructing the algorithms, it is possible to use fewer time steps to achieve higher fidelity simulations.

MOPR040 **A Single-Turn Map Formalism for Collective Effects**

Stephen Davis Webb (RadiaSoft LLC, Boulder, Colorado)

The concept of a single-turn map provides considerable insight into the long-term single particle dynamics in storage rings. Using a factored map formalism and a Hamiltonian perturbation theory for plasmas, we derive a first order perturbative treatment of collective effects in rings. This allows us to extend the single-turn map formalism to include collective effects. This treatment goes beyond the constant focusing channel approximation, and can be extended to include a variety of physical effects not previously considered.

MOPL001 **Instability in the nonlinear envelope dynamics of a bunched beam**

Thales Marques Correa da Silva, Renato Pakter, Felipe Barbedo Rizzato (IF-UFRGS, Porto Alegre)

In this work, we analyze the envelope equations for a bunched beam with ellipsoidal symmetry. We focus in beams where space charge effects are dominant. As a consequence, the longitudinal and transverse envelope dynamics are coupled. While linear analysis shows that the system is always stable for infinitesimal perturbations, when taking into account nonlinear terms, we observe instabilities for certain parameters, which include regions of very small mismatch (where the system is almost linear). We map the region of parameters in which the system is unstable. One of the consequences of this instability is the exchange of energy between the degrees-of-freedom. This may lead to a large increase of the envelope amplitude in one direction due to a mismatch in the other direction. We solve the envelope equations to show this effect.

MOPL002 **THE DESIR FACILITY AT GANIL-SPIRAL2: THE TRANSFER BEAM LINES**

Luc Perrot, Philippe Blache, Sébastien Rousselot (IPN, Orsay)

The new ISOL facility SPIRAL2 is currently being built at GANIL, Caen France. The commissioning of the accelerator is in progress since 2015. SPIRAL2 will produce a large number of new radioactive ion beams (RIB) at high intensities. In 2019, the DESIR facility will receive beams from the upgraded SPIRAL1 facility of GANIL (stable beam and target fragmentation), from the S3 Low Energy Branch (fusion-evaporation and deep-inelastic reactions). In order to deliver the RIB to the experimental set-ups installed in the DESIR hall, 110 meters of beam line are studied since 2014. This paper will focus on the recent studies which have been done on these transfer lines: beam optics and errors calculations, quadrupoles, diagnostics and mechanical designs.

MOPL003 **Status of the Beam Dynamics Design of the New Post-Stripper DTL for GSI-FAIR**

Anna Rubin, David Daehn, Xiaonan Du, Lars Groening, Michael Kaiser, Sascha Mickat (GSI, Darmstadt)

The GSI UNILAC has served as injector for all ion species since 40 years. Its 108 MHz Alvarez DTL providing acceleration from 1.4 MeV/u to 11.4 MeV/u has suffered from material fatigue and has to be replaced by a new section. The design of the new post-stripper DTL is now under development in GSI. An optimized drift tube shape increases the shunt impedance and varying stem orientations mitigate parasitic rf-modes. This contribution is on the beam dynamics layout.

MOPL004 **Beam Dynamics Simulation and Code Comparison for New CW RFQ Design**

Sergey Markovich Polozov (MEPhI, Moscow), Winfried A. Barth (GSI, Darmstadt; HIM, Mainz; MEPhI, Moscow), Stepan Yaramyshev (GSI, Darmstadt; MEPhI, Moscow), Timur Kulevoy (ITEP, Moscow; MEPhI, Moscow)

Research and development of CW applications is an important step in RFQ design. The RF potential should be limited by 1.3-1.5 of Kilpatrick criterion for the CW mode. A 2 MeV RFQ is under development for the compact CW research proton accelerator, as well as for planned driver linac* in Russia. The maximum beam current is fixed to10 mA; the operating frequency has been set to 162 MHz. The new RFQ linac design will be presented and beam dynamics simulation results will be discussed. Calculations of beam dynamics are provided using the codes BEAMDULAC (developed at MEPhI for linac design) and DYNAMION. A comparison of the software performance is presented.

MOPL005 **Simulation study of beam dynamics on linac for CSNS during commissioning**

Yue Yuan, Hongfei Ji, Sheng Wang (IHEP, Beijing), Jun Peng (CSNS, Guangdong Province)

Due to the difference of actual effective length and theoretical effective length of magnets in MEBT and DTL, in order to compare its impact of beam transport, this paper take a beam dynamics simulation on beam transport in MEBT and DTL with IMPACT-Z code. In addition, in the beam commissioning of linac, the match between MEBT and DTL is good or bad will directly affect the commissioning of DTL. In the initial beam commissioning , we tend to use theoretical lattice of MEBT. But due to space charge effects and error of magnet, the phase ellipse of beam will rotate a certain angel at the exit of MEBT, and cause the mismatch between MEBT and DTL. There are no measurement elements at entrance of the DTL, so the specific parameters of beam can not be given. Therefore, some different lattice of MEBT with artificial mismatch can be given, then the best lattice of MEBT may be found when the beam transport efficiency is nearly 100% in DTL1.

MOPL006 **Beam Dynamics Study of C-ADS Injector-I With Developed P-TOPO Code**

Zhicong Liu (IHEP, Beijing)

A full parallelized, time-dependent 3D and 2D simulation code is developed to study the high-intensity beam dynamics in linear accelerator. The self-consistent space charge effect is taken into account using Particle-In-Cell method. In this paper, firstly, the structure of program and the parallel strategy with a performance test are demonstrated. Then, the benchmark of this code is shown in detail. It is proved that the paralleling strategy solver used in program reliable. Finally, the code is used to study beam dynamics and beam loss problems in C-ADS Injector-I at IHEP. The possible reasons for the differences between simulation result and measured result are also proposed.

MOPL007 **Beam Steering Studies for the Superconducting Linac of the RAON Accelerator**

Hyunchang Jin, Ji-Ho Jang, Dong-O Jeon (IBS, Daejeon)

The RAON accelerator of Rare Isotope Science Project (RISP) has been developed to accelerate various kinds of stable ion beams and rare isotope beams for a wide range of science experiments. In the RAON accelerator, the superconducting linac (SCL) will be installed for the acceleration of the beams and it is composed of tens of cryomodules which include superconducting radio frequency cavities. Between two cryomodules, there is a warm section and two quadrupoles are located in the warm section with a beam diagnostics box in between. Also, in this warm section, one horizontal corrector and one beam position monitor (BPM) are mounted inside of first quadrupole, and one vertical corrector is located inside of second quadrupole for the beam steering. With these correctors and BPMs, the beam steering studies are carried out as varying the number of correctors and BPMs in the SCL of the RAON accelerator and the results are presented.

MOPL009 **Analytical Approach for Achromatic Structure Study and Design**

Helen Barminova (MEPhI, Moscow), Alexander Sergeevich Chikhachev (All-russian Electrotechnical Institute, Moskow)

The analytical approach is proposed to study the various achromatic structures. The method is based on the self-consistent time-dependent models, which allow to describe the dynamics of both continuous and bunched beam in external magnetic fields. The fully kinetic models are implemented in this approach. The kinetic distribution functions dependent on the motion integrals allow to obtain accurate Vlasov equation solutions as KV-model does it. The method allows to solve the envelope equation both analytically and by ODE system numerical integration, and to predict the beam phase portrait behavior in magnetic fields of the structure. The advantages of the method are the possibility of easy scaling and the wide physical generality, which is important for the multi-parameter problem of the high-intensity high-brightness beam formation. The results of the method application for the bending magnets and the quadrupoles are presented.

Beam Instruments and Interactions, Monday, 2016 July 4, 16:00-18:00

MOPL010 **ESSnuSB Project to Produce Intense Beams of Neutrinos and Muons**

Elian Bouquerel (IPHC, Strasbourg Cedex 2)

A new project for the production of a very intense neutrino beam has arisen to enable the discovery of a leptonic CP violation. This facility will use the worldŠs most intense pulsed spallation neutron source, the European Spallation Source (ESS) under construction in Lund. Its linac is expected to be fully operational at 5 MW power by 2023, using 2 GeV protons. In addition to the neutrinos, the ESSnuSB proposed facility will produce a copious number of muons at the same time. These muons could be used by a future Neutrino Factory to study a possible CP violation in the leptonic sector and neutrino cross-sections. They could also be used by a muon collider or a low energy nuSTORM. The layout of such a facility, consisting in the upgrade of the linac, the use of an accumulator ring, a target/horn system and a megaton Water Cherenkov neutrino detector, is presented. The physics potential is also described.

MOPL011 **Laser Stripping H- Charge Exchange Injection by Femtosecond Lasers**

Timofey Gorlov (ORNL, Oak Ridge, Tennessee)

A new method for H- laser assistant charge exchange injection using femtosecond laser pulses is considered. The existing method uses a divergent laser beam that allows compensation of angular and momentum spread of the stripped beam. The femtosecond laser pulse has a similar property that can compensate the spread and yield efficient laser stripping. Results of simulations with realistic femtosecond laser and H- beam parameters are discussed. The proposed method may have some benefit for particular technical conditions compared with others.

MOPL012 **Residual Dose Measurement and Activation of the Injection Area in the J-PARC RCS**

Masahiro Yoshimoto, Hideaki Hotchi, Shinichi Kato, Michikazu Kinsho, Kota Okabe (JAEA/J-PARC, Tokai-Mura, Naka-Gun, Ibaraki-Ken)

In the 3 GeV Rapid Cycling Synchrotron (RCS) of Japan Proton Accelerator Research Complex (J-PARC), we adopted multi-turn H- charge exchange injection by using stripper foil in order to achieve high power proton beam. It is therefore impossible to neglect the interaction between stripper foil and the beam. As a result, there are high residual dose measured around the stripper foil. Based on detail numerical simulations by using PHITS code, it is identified that the secondary particles produced in the nuclear reactions due to foil beam interaction caused the high residual activity around foil. In this paper, we report a detail measurement of the residual dose around the stripper foil together with the cause estimated based on simulation studies.

MOPL013 **The Charge Exchange Type Beam Halo Scraper at the J-PARC L3BT**

Kota Okabe, Kazami Yamamoto (JAEA/J-PARC, Tokai-mura), Shinichi Kato (JAEA/J-PARC, Tokai-Mura, Naka-Gun, Ibaraki-Ken)

To mitigate the beam loss at the Japan Proton Accelerator Research Complex (J-PARC) 3-GeV rapid cycle synchrotron (RCS), it is necessary to improve the quality of the injection beam from the Linac. Thus, we developed a charge-exchange type scraper system with a thin carbon foil to collimate the beam halo in the injection beam line of the RCS. The key issue to realize the scraper is a reduction of the beam loss induced by the multiple-scattering effect of charge-exchange foil. A particle-tracking simulation study with the G4beamline has been performed for the scraper system, assuming a realistic halo at the scraper section. Using this result, we chose the thickness of a 520 ug/cm2 as the scraper foils to mitigate radiation dose around the scraper section. A charge-exchange scraper system that prevents the emission of radioactive fragments of the carbon foil was build. From the result of a preliminary beam experiments, we confirmed that the installed scrapers eliminate a transverse beam tail or halo. After two days of operation with beam scraping, the residual dose level around the installed scrapers was tolerable for the hands-on maintenance.

MOPL015 **Effect of Beam Losses on Wire Scanner Scintillator Readout, Hypothesis and Preliminary Results**

Benjamin Cheymol (ESS, Lund)

In hadron accelerators, the characterization of the beam transverse halo can lead to a better understanding of the beam dynamics and ultimately to a reduction of the beam losses. Unfortunately the effect of losses on beam instrumentation implies a reduction of the instrument sensitivity due to the background noise. In this paper, we will discuss the effect of losses on the wire scanner scintillator foreseen for the ESS linac, in particular the different hypothesis for the input will be described and preliminary results will be presented.

MOPL016 **Effects of Energy Deposition Models and Conductive Cooling on Wire Scanner Thermal Load, Analytical and Finite Element Analysis Approach**

Benjamin Cheymol (ESS, Lund)

One of the main limitations of the wire scanner in high intensity linac is the inability of the wire to survive at high duty cycle. For the commissioning of such machines, duty cycle must be reduced to preserve interceptive devices. A good thermal model of the wire is needed to insure a safe operation of the wire scanner and set the limits of acceptable beam duty cycle. In this paper, we will discuss the influence of the energy deposition model and the efficiency of conductive cooling on the wire temperature, based on the ESS beam parameters.

MOPL017 **High Power and High Duty Cycle Slit and Grid System for Hadron Accelerator Commissioning**

Benjamin Cheymol, Aurélien Ponton (ESS, Lund)

Transverse emittance is one of the key measurements to be performed during the commissioning of the low energy sections of an hadron linac. The good knowledge of the beam transverse phase space allows a safe and efficient operation of the machines by using the results of the measurement for beam dynamic simulations. In this paper we will discuss the accuracy and the limits of the transverse emittance measurement performed with the slit-grid method based on the ESS beam parameters at the RFQ (beam energy equal to 3.62 MeV) and DTL tank 1 (beam energy equal to 21 MeV) output.

MOPL018 **Scintillator Detectors for the ESS High Energy Wire Scanner**

Benjamin Cheymol (ESS, Lund)

In the ESS linac, during commissioning and restart phase, wire scanner will be used intensively to characterize the transverse beam profiles. At low energy, the mode of detection is based on Secondary Emission (SE), while at energies above 200 MeV, the primary mode of detection will be the measurement of the hadronic shower created in the thin wire. In this paper we will present the design and the output signal estimation of the shower detector, based on inorganic crystal and silicon photodetector.

MOPL019 **Results From First Crystal Collimation Tests at the Large Hadron Collider**

Stefano Redaelli, Daniele Mirarchi, Roberto Rossi, Walter Scandale (CERN, Geneva)

Crystal collimation is a technique that relies on highly pure bent crystals to coherently deflect beam haloÊparticles - through the channeling mechanisms - onto dedicated absorbers. Standard multi-stage collimation systems for hadron beams use amorphous materials as primary collimators and might be limited byÊnuclear interactions and ion fragmentation that are strongly suppressed in crystals. A crystal collimation setup wasÊinstalled in the betatron cleaning insertion of the Large Hadron Collider (LHC) to demonstrate with LHC beams the feasibility of this concept and to compare its performance with that of the present system. The channeling was observed for the first time and the halo cleaning efficiency could be measured. Results of these first beamÊtests are presented.

MOPL020 **Online Measurement of the Energy Spread of Multi-turn Beam in the Fermilab Booster at Injection**

Chandra Bhat, Brian Scott Hendricks (Fermilab, Batavia, Illinois), Jovan Nelson (Brown University, Providence)

Abstract: We have developed a computer program interfaced with the ACNET environment for Fermilab accelerators to measure energy spread of the proton beam from the LINAC at an injection kinetic energy of 400 MeV. It uses a digitizing oscilloscope and provides the user the ability to configure scope settings for optimal data acquisition from a resistive wall monitor. When the program is launched, it secures complete control of the scope. Subsequently, a special Şone-shotŤ timeline is generated to initiate the beam injection into the Booster. After the completion of the beam injection from the LINAC, a gap of about 40 ns is produced in the Booster beam using a set of kickers and line-charge distribution data is collected for next 200 microsec. The program then analyzes the data to extract the gap width, beam revolution period and beam energy spread. We illustrate a case with an example. We also present results on beam energy spread as a function of beam intensity from a recent measurement.

MOPL021 **Fermilab Booster Transition Simulations and Beam Studies**

Chandra Bhat, Cheng-Yang Tan (Fermilab, Batavia, Illinois)

The Fermiab Booster accelerates beam from 400 MeV to 8 GeV at 15 Hz. In the PIP (Proton Improvement Plan) era, it is required that Booster deliver 4.2e12 protons per pulse to extraction. One of the obstacles for providing quality beam to the users is the longitudinal quadrupole oscillation that the beam suffers from right after transition. Although this oscillation is well taken care of with quadrupole dampers, it is important to understand the source of these oscillation in light of the PIP II requirements that require 6.5e12 protons per pulse at extraction. This paper explores the results from computer simulations, machine studies and solutions to prevent the quadrupole oscillation after transition.

MOPL024 **MAGNET SORTING FOR THE CSNS/RCS USING FIELD MEASUREMENT DATA***

Yuwen An, Hongfei Ji, Yong Li, Sheng Wang, Shou Yan Xu (IHEP, Beijing), Jun Peng (CSNS, Guangdong Province)

The Rapid Cycling Synchrotron (RCS) is the main important part of China Spallation Neutron Source (CSNS) Project, which accumulates and accelerates the proton beam from 80 MeV to 1.6 GeV for extraction and striking the target with a repetition rate of 25 Hz. RCS consists of 48 quadrupoles with five power supplies and 24 dipoles sharing one power supply. Before installed to tunnel, the field measurements of the quadrupoles and dipoles were carefully done in DC mode and AC mode. The magnet field measurement data in DC mode was used to sort magnets for a lower beta-beating and a smaller closed orbit distortion (COD). Here we present details of the method and results of the quadrupoles and dipoles sorting at CSNS/RCS.

Commissioning and Operations, Monday, 2016 July 4, 16:00-18:00

MOPL025 **Transient Beam Loading Based Calibration for Cavity Phase and Amplitude Setting**

Rihua Zeng (ESS, Lund), Olof Troeng (Lund University, Lund)

Traditional phase scan method for cavity phase and amplitude setting is offline and hard to track the variations of environment and operation points. An alternative beam loading based calibration method is investigated in this paper, which might become useful online/real time calibration method.

7.5 Tuesday

Beam Dynamics in Rings, Tuesday, 2016 July 5, 9:00-12:40

TUAM1X01 **A Two Particle Model for Study of Effects of Space-Charge Force on Strong Head-Tail Instabilities.**

Yong Ho Chin (KEK, Ibaraki), Michael Blaskiewicz (BNL, Upton, Long Island, New York), Yoshihiro Shobuda (JAEA/J-PARC, Tokai-Mura, Naka-Gun, Ibaraki-Ken), Alex Chao (SLAC, Menlo Park, California)

In this talk, I present a new two particle model for study of strong head-tail instabilities in the presence of the space-charge force. It is a simple expansion of the well-known two particle model. No chromaticity effect is included. It leads to a formula for the growth rate as a function of the two dimensionless parameters: the space-charge tune shift parameter (normalized by the synchrotron tune) and the wake field strength, Y. The 3-dimensional contour plot of the growth rate as a function of those two dimensionless parameters reveals stopband structures. Many simulation results generally indicate that a strong head-tail instability can be damped by a weak space-charge force, but the beam becomes unstable again when the space-charge force is further increased. The new two particle model indicates a similar behavior. In weak space-charge regions, additional tune shifts by the space-charge force dissolve the mode-coupling. As the space-charge force is increased, they conversely re-

store the mode-coupling, but then a further increase of the space-charge force decouples the modes again. This mode coupling/decoupling behavior creates the stopbands structures.

TUAM2X01 **Measurement and Interpretation of Transverse Beam Instabilities in the CERN Large Hadron Collider (LHC) and Extrapolations to HL-LHC**

Elias Métral, Gianluigi Arduini, Nicolo Biancacci, Xavier Buffat, Lee Robert Carver, Giovanni Iadarola, Kevin Shing Bruce Li, Tatiana Pieloni, Annalisa Romano, Giovanni Rumolo, Benoit Salvant, Michael Schenk, Claudia Tambasco (CERN, Geneva), Javier Barranco (EPFL, Lausanne)

Since the first transverse instability observed in 2010, many studies have been performed on both measurement and simulation sides and several lessons have been learned. In a machine like the LHC, not only all the mechanisms have to be understood separately, but the possible interplays between the different phenomena need to be analyzed in detail, including the beam-coupling impedance (with in particular all the necessary collimators to protect the machine but also new equipment such as crab cavities for HL-LHC), linear and nonlinear chromaticity, Landau octupoles (and other intrinsic nonlinearities), transverse damper, space charge, beam-beam (long-range and head-on), electron cloud, linear coupling strength, tune separation between the transverse planes, tune split between the two beams, transverse beam separation between the two beams, etc. This paper reviews all the transverse beam instabilities observed and simulated so far, the mitigation measures which have been put in place, the remaining questions and challenges and some recommendations for the future.

TUAM3X01 **Identification and Reduction of the CERN SPS Impedance**

Elena Shaposhnikova (CERN, Geneva)

The first SPS impedance reduction programme has been completed in 2001, preparing the ring for its role as an injector of the LHC. This action has eliminated microwave instability on the SPS flat bottom and later nominal beam could be delivered to the LHC. The High Luminosity (HL-) LHC project is based on beam with twice higher intensity than the nominal one. One of the important SPS intensity limitations are longitudinal instabilities with minimum threshold reached on the 450 GeV flat top. In this paper the work which was carried on to identify the impedance sources driving these instabilities is described together with the next campaign of the SPS impedance reduction planned by the LHC Injector Upgrade (LIU) project. The present knowledge of the SPS transverse impedance is also presented.

TUAM4X01 **Electron Cloud Effects in the CERN Accelerator Complex**

Giovanni Rumolo (CERN, Geneva)

Operation with closely spaced bunched beams causes the build up of an Electron Cloud (EC) in both the LHC and the two last synchrotrons of its injector chain (PS and SPS). Pressure rise and beam instabilities are observed at the PS during the last stage of preparation of the LHC beams. The SPS was affected by coherent and incoherent emittance growth along the LHC bunch train over many years, before scrubbing has finally suppressed the EC in a large fraction of the machine. When the LHC started regular operation with 50 ns beams in 2011, EC phenomena appeared in the arcs during the early phases, and in the interaction regions with two beams all along the run. Operation with 25 ns beams (late 2012 and 2015), which is nominal for LHC, has been hampered by EC induced high heat load in the cold arcs, bunch dependent emittance growth and degraded beam lifetime. Dedicated and parasitic machine scrubbing is presently the weapon used at the LHC to combat EC in this mode of operation. This talk summarises the EC experience in the CERN machines (PS, SPS, LHC) and highlight the dangers for future operation with more intense beams as well as the strategies to mitigate or suppress the effect.

TUAM5X01 **Space Charge Driven Beam Loss for Cooled Beams and Possible Mitigation Measures in the CERN Low Energy Ion Ring**

Hannes Bartosik, Steven Hancock, Alexander Huschauer, Verena Kain (CERN, Geneva)

The performance of the CERN Low Energy Ion Ring (LEIR) with electron cooled lead ion beams is presently limited by losses, which occur during RF capture and the first part of acceleration. Extensive experimental studies performed in 2015 indicate that the losses are caused by the interplay of betatron resonances and the direct space charge detuning, which is significantly enhanced during bunching. Mitigation measures have already been identified and successfully tested, such as reducing the peak line charge density after RF capture, i.e. increasing the longitudinal emittance, and compensating third order resonances using existing harmonic sextupole correctors. New record intensities at extraction could be achieved. This talk describes the main experimental results from the 2015 measurement campaign including already implemented mitigation measures and the proposed strategy for even further increasing the LEIR intensity reach in the future.

TUAM6X01 **Space Charge Effects on the Third Order Coupled Resonance**

Giuliano Franchetti (GSI, Darmstadt)

The effect of space charge on bunches stored for long term in a nonlinear lattice can be severe for beam survival. This may be the case in projects as SIS100 at GSI or LIU at CERN. In 2012, for the first time, the effect of space charge on a normal third order coupled resonance was investigated at the CERN-PS. The experimental results have highlighted an unprecedented asymmetric beam response whereÊin the horizontal plane the beam exhibits a thick halo, whereas the vertical profile has only core growth. The quest for explaining these results requires a journey thorough the 4 dimensional dynamics of the coupled resonance investigating the fix-lines, and requires a detailed code-experiment benchmarking also including beam profile benchmarking. This study shows that the experimental results of the 2012 PS measurements can be explained by the dynamics the fixed lines also including the effect of the chromaticity. This open the way for studying the effect of space charge on any high order sum nonlinear coupled resonance.

TUAM7X01 **Intensity Effects in the Formation of Stable Islands in Phase Space During the Multi-Turn Extraction Process at the CERN Ps**

Shinji Machida (STFC/RAL/ASTeC, Chilton, Didcot, Oxon), Simone Silvano Gilardoni, Massimo Giovannozzi, Alexander Huschauer (CERN, Geneva), Christopher Prior (STFC/RAL/ISIS, Chilton, Didcot, Oxon)

The CERN PS utilises a multi-turn extraction (MTE) scheme to stretch the beam pulse length to optimise the filling process of the SPS. MTE is a novel technique to split a beam in transverse phase space into nonlinear stable islands. The recent experimental results indicate that the positions of the islands depend on the total beam intensity. Particle simulations have been performed to understand the detailed mechanism of the intensity dependence. The analysis carried out so far suggests space charge effects through image charges and image currents on the vacuum chamber and the magnetsŠ iron cores dominate the observed behaviour. In this talk, the latest analysis with realistic modelling of the beam environment is discussed and it is shown how this further improves the understanding of intensity effects in MTE.

TUAM8X01 **Beam-Beam Effects in the Large Hadron Collider**

Tatiana Pieloni (CERN, Geneva)

The Large Hadron Collider (LHC) is operating at an energy of 6.5 TeV and in 25 ns bunch spacing very close to the design values. For the 2015 physics RUN beam-beam effects have been kept weak in order to gain experience with other effects (i.e. impedance, e-cloud). The 2016 physics run will perform at stronger long-range effects. Several experiments devoted to highlight the beam-beam limits have been carried out during the year in order to define possible future scenarios with the aim to maximize the integrated luminosity. In this paper the beam-beam effects observed during physics fills and devoted experiments will be presented with considerations on the possible limitations for future operation of the LHC and extrapolations to HL-LHC.

TUPM1X01 **Broadband Feedback System for Instability Damping in the SNS Ring**

Nicholas John Evans (ORNL RAD, Oak Ridge, Tennessee)

Shortly after operation of the Spallation Neutron Source began, broadband transverse motion of the proton beam in the Accumulator Ring attributed to electron-proton interaction was observed from 80-120MHz. No significant losses due to e-p have been seen to date during normal operation, but to mitigate against the possibility of an intensity limiting instability a broadband feedback system was designed and implemented. The SNS feedback system is based on a delay-line model with additional flexibility from digital signal processing to control delay and gain, and correct phase dispersion due to cabling. Relative to mode-by-mode dampers (or an equivalent time domain implementation) that condition the phase of each mode independently, this design simplifies the hardware needed to damp the broadband oscillations, but requires tuning the accelerator for optimal performance to minimize delay between sensing and affecting beam motion. This talk will discuss the requirements and challenges specific to the SNS damper. Results showing the damper effectively suppressing broadband motion attributed to e-p activity during normal operation of the SNS accelerator will also be presented.

TUPM2X01 **Heavy Ion Charge Stripping at FRIB**

Felix Marti, Paul Guetschow (FRIB, East Lansing, Michigan), Yoichi Momozaki, Claude Reed (ANL, Argonne, Illinois), Jerry Nolen (ANL, Argonne, Illinois; FRIB, East Lansing, Michigan), Ady Hershcovitch, Peter Thieberger (BNL, Upton, Long Island, New York), Michael LaVere (MSU, East Lansing, Michigan)

The Facility for Rare Isotope Beams being built at Michigan State University includes a high intensity superconducting radio frequency heavy ion linac. This driver linac will accelerate ions up to uranium to energies above 200 MeV/u at 400 kW beam power. The design includes a charge stripper at energies between 16 and 20 MeV/u. The estimated power deposition in a conventional carbon foil stripper would require power densities of the order of 30 MW/cm3. We are developing two types of charge strippers with self-replenishing fluids, a liquid (lithium) and a gas (helium) version. We present in this talk a description of the R&D, the expected pros and cons of each method, and the status of the construction of both systems.

TUPM3X01 **R&D on Beam Injection and Bunching Schemes in the Fermilab Booster**

Chandra Bhat (Fermilab, Batavia, Illinois)

Fermilab is committed to upgrade its accelerator complex towards the intensity frontier by making a substantial increase in the average beam power delivered to the neutrino and muon programs pursuing HEP research in the lepton sector. Proton Improvement Plan (PIP) enables us to provide 700 kW beam power by the end of this year. By the middle of next decade, the foreseen PIPŰII replaces the existing LINAC, a 400 MeV injector to the Booster, by an 800 MeV superconducting LINAC with beam power increased by >50%. In any case, the Fermilab Booster, an 8 GeV injector to the MI, is going to play a very significant role for the next two decades. In this context, we have recently developed an innovative beam injection scheme for the Booster called "early injection scheme" and put into operation. This novel scheme has a potential to increase the Booster beam intensity from the PIP design goal by 40%. Some benefits of the scheme have already been seen so far. In this talk, I will present, principle of the scheme, results from beam experiments, current status and future plans for the early beam injection scheme. This scheme fits well with the current and future programs at Fermilab.

TUPM4X01 **LHC Injectors Upgrade for the HL-LHC**

Chiara Bracco, Julie Coupard, Heiko Damerau, Anne Funken, Brennan Goddard, Klaus Hanke, Alessandra Maria Lombardi, Django Manglunki, Simon Mataguez, Malika Meddahi, Bettina Mikulec, Giovanni Rumolo, Richard Scrivens, Elena Shaposhnikova, Maurizio Vretenar (CERN, Geneva)

The goal of the HL-LHC is to increase the LHC peak nominal Luminosity by a factor of seven in order to provide more accurate measurements of new particles and enable observation of rare processes that occur below the current sensitivity level. Achieving this target requires to double the beam intensity and reduce the emittance by 40%. All the LHC injectors, from the LINAC to the Super Proton Synchrotron (SPS) including the heavy ion chain, have to be improved to reliably supply such high brightness beams to the HL-LHC. The upgrade campaign will be completed during the Second Long Shutdown (LS2) in 2019-2020. The performance objectives and the status of this challenging program is presented.

TUPM5X01 **Injecting Painting Improvements in the J-PARC RCS**

Shinichi Kato, Norimitsu Tobita (JAEA/J-PARC, Tokai-Mura, Naka-Gun, Ibaraki-Ken), Hideo Harada (JAEA, Ibaraki-ken), Koki Horino, Hideaki Hotchi, Michikazu Kinsho, Kota Okabe, Pranab Kumar Saha, Tomohiro Takayanagi, Tomoaki Ueno (JAEA/J-PARC, Tokai-mura)

In the J-PARC 3GeV RCS, the injection painting is essential method for the reduction of the space charge force. In this method, the H- beam from Linac is arranged on the large phase space area of the ring orbit during multiple turns. To implement this method, painting magnets form the time variable beam orbit. Therefore, the precise output current control of the magnet power supply is required. Because the power supply controlled by mainly feedforward signal is operated, we developed the iterative tuning method for the optimum feedforward parameter determination. As a result, we could reduce the tracking error of the current compared to before. Furthermore, to improve the accuracy of the painting area size, we applied the output readjustment additionally. Because the current monitor value of the power supply was different from the actual magnetic field due to the delay in the circuit and the leakage field, we corrected the tracking of the current based on the measured painting area size determined by the analysis of the measured COD. As a result, we achieved the precise injection painting. This talk presents these improvement results of the injection painting in the RCS.

TUPM6X01 **H- Charge Exchange Injection Issues at High Power**

Michael Plum (ORNL, Oak Ridge, Tennessee)

At low beam powers H- charge exchange injection into a storage ring or synchrotron is relatively simple. A thin stripper foil removes the two convoy electrons from the H- particle and the newly-created proton begins to circulate around the ring. At high beam powers there are complications due to the heat created in the stripper foil, the power in the H0 excited states, and the power in the convoy electrons. The charge-exchanged beam power at the Oak Ridge Spallation Neutron Source is the highest in the world. Although the SNS ring was carefully designed to operate at this level there have been surprises, primarily involving the convoy electrons. Examples include damage to the foil brackets due to reflected convoy electrons and damage to the electron collector due to the primary convoy electrons. The SNS Second Target Station project calls for doubling the beam power and thus placing even more stress on the charge-exchange-injection beam-line components. In this presentation we will compare charge-exchange-injection designs at high-power facilities around the world, discuss lessons learned, and describe the future plans at SNS.

TUPM7X01 **An Experimental plan for 400 MeV H- Stripping to Protons by using only Laser system in the J-PARC RCS**

Pranab Kumar Saha, Hiroyuki Harada, Shinichi Kato, Michikazu Kinsho (JAEA/J-PARC, Tokai-Mura, Naka-Gun, Ibaraki-Ken), Yoshiro Irie, Isao Yamane (KEK, Ibaraki)

The 3-GeV RCS (Rapid Cycling Synchrotron) of J-PARC is gradually approaching to the design operation with 1 MW beam power. Studies are ongoing for further higher beam power of 1.5 MW. The injection and extraction energy of RCS is 0.4 and 3 GeV, respectively. Lifetime of the stripper foil is the highest concern beyond 1 MW beam power. We have also already started detail studies of H- stripping to protons by using lasers. However, in order to avoid high magnetic field required in the process of laser-assisted H- stripping to protons, especially for lower H- energies, we are studying the possibilities of using only laser system for 400 MeV H- beam in the RCS. The method is a three step process, similar to that of SNS but lasers are used instead of high field magnets in the 1st (H- to H0) and 3rd step (H0* to p). A Nd:YAG laser can be properly used for both 1st and 3rd steps, where commercially available powerful Excimer laser will be used an H0 excitation in the 2nd step. Although detail R&D studies are necessary to reach to the ultimate goal, we plan to carry out an experiment in 2017. A detail of the present method, experimental schedule and the expected outcome will be presented.

TUPM8X01 **First results of laser-assisted H- stripping of a 10 us, 1 GeV beam at the SNS accelerator**

Sarah M. Cousineau (ORNL, Oak Ridge, Tennessee)

Laser-assisted H- stripping has been successfully performed for a 10 us, 1 GeV H- beam at the SNS accelerator. Here we discuss the configuration of the experiment, the associated challenges, and the final results including stripping efficiencies and parameter sensitivities.

TUAM1Y01 **SARAF Phase-I Experience with mA Beams**

Dan Berkovits (Soreq NRC, Yavne)

The RF superconducting (SC) linac at the Soreq Applied Research Accelerator Facility (SARAF) is designed for CW 5 mA 40 MeV proton and deuteron beams. SARAF Phase-I has been built to test and characterize the required novel technologies. Phase-I includes a 20 keV/u ECR ion source, a LEBT, a 4 m long 176 MHz 4-rod RFQ, a short MEBT, one 4K SC module that hosts 6 HWRs and 3 SC solenoids and 13 m long beam lines for beam and basic studies. Since 2011, SARAF Phase-I was the first accelerator to use HWR and the first to accelerate variable energy 2 mA CW protons beam. Beam dynamics simulations are used in the design phase, for everyday beam tuning and for beam studies. However, the simulation predictions of the RFQ transmission and the SC linac beam loss donŠt reach the required level of confidence. This is assumed to be due to unknown absolute values of initial beam distribution, LEBT space charge compensation, components misalignment and more. The experience of matching beam dynamics phenomena to beam measurements will be presented.

TUAM2Y01 **Beam Dynamics Challenges in IFMIF**

Nicolas Chauvin, Phu Anh Phi Nghiem, Didier Uriot (CEA/IRFU, Gif-sur-Yvette), Concepcion Oliver (CIEMAT, Madrid), Michele Comunian (INFN/LNL, Legnaro (PD))

The International Fusion Materials Irradiation Facility will produce a high flux (10e18 n.m-2 .s-1) of 14 MeV neutron dedicated to characterization and study of candidate materials for future fusion reactors. To reach such a goal, a solution based on two high power cw accelerator drivers, each delivering a 125 mA deuteron beam at 40 MeV to a liquid lithium target, is foreseen. With theses accelerators, a simultaneous combination of unprecedentedly high intensity, power (2×5 MW) and space charge has to be addressed. In this paper, special considerations and concepts that have been developed to overcome these challenges are introduced. The methods that have been applied for beam loss prediction, optimization, beam diagnostic and characterization are presented. Then, in order to have a better understanding of beam loss mechanisms along the accelerator, massive computing activities have been launched: end-to-end particle simulations using a number of macro-particle that corresponds to the actual number of particles that will populate a bunch in the real IFMIF machine. The obtained simulation results are presented and discussed in terms of beam halo and emittance growth.

TUAM3Y01 **Beam Dynamics Challenges in the ESS Linac**

Yngve Inntjore Levinsen, Renato De Prisco, Mohammad Eshraqi, Ryoichi Miyamot
(ESS, Lund)

The European Spallation Source will be the worlds brightest neutron source. It will be driven by a 5 MW proton linac that delivers a 2.86 ms pulse at 14 Hz, which means the peak beam power is 125 MW. This requires a careful design of the lattice structures in order to allow for safe and reliable operation of the accelerator. We will discuss some of the design choices and some of the particular challenges that were faced during the design of the ESS lattice.

TUAM4Y01 **Instability Investigation of the China ADS Injector-I Testing Facility**

Fang Yan (IHEP, Beijing)

The instablility of the China ADS SC section of the injector-I testing facility is investigated. The performance of the beam footprinted at different positions of the instability chart are studies using program and compared with experiment results. A moderate design was chosen to avoid envelope resonances or equipartitioning between different freedom of planes. The longitudinal acceptance is determined by the stabilization of the cavity phase and amplitude. The details will be reported in this presentation.

TUAM5Y01 **Beam Simulation Studies for FRIB**

Qiang Zhao (FRIB, East Lansing, Michigan)

we will report the recent beam simulation studies on the FRIB driver linac.

TUAM6Y01 **Experimental Investigation of Emittance Exchange in J-PARC Linac With Non-Equipartitioning Setting**

Yong Liu (KEK/JAEA, Ibaraki-Ken), Masanori Ikegami (FRIB, East Lansing, Michigan), Tomofumi Maruta (J-PARC, KEK & JAEA, Ibaraki-ken), Akihiko Miura (JAEA/J-PARC, Tokai-mura), Tomoaki Miyao (KEK, Ibaraki), Ciprian Plostinar (STFC/RAL/ASTeC, Chilton, Didcot, Oxon)

J-PARC is on the way to 1 MW operation step by step. J-PARC linac complected upgrade to 50 mA/400MeV in 2014, and the next main tasks of beam study are to optimize beam loss and output emittance for 40 mA and 50 mA operation. Residue radiation level at a lower repetition predicted that the beam loss becomes close to the maintenance limit in case of full operation at 50 mA. And intra-beam stripping (IBSt) effect in the H- beam is found to be the dominant source of the beam loss here. IBSt is only sensitive to lattice, so that the only solution is to be away from J-PARC baseline design with equipartitioning condition, in a safe way. In the previous work, emittace exchange and break of periodicity were predicted by the simulation and they are consistent with the "Hofmann chart". Series of experiments were carried out, not only for investigation of new lattice with controlled beam loss and emittance but also for a better understanding of rules of lattice optimization and the physics behind.

TUAM7Y11 **High Current Uranium Beam Measurements at GSI UNILAC for FAIR**

Winfried A. Barth, Aleksey Adonin, Manuel Heilmann, Ralph Hollinger, Egon Jaeger, Oliver Karl Kester, Joerg Krier, Evgenij Plechov, Wolfgang Vinzenz, Hartmut Vormann (GSI, Darmstadt), Jadambaa Khuyagbaatar, Alexander Yakushev (GSI, Darmstadt; HIM, Mainz), Christoph Emanuel Duellmann (GSI, Darmstadt; HIM, Mainz; Johannes Gutenberg University Mainz, Mainz), Paul Scharrer (GSI, Darmstadt; HIM, Mainz; Mainz University, Mainz), Stepan Yaramyshev (GSI, Darmstadt; MEPhI, Moscow)

In the context of an advanced machine investigation program supporting the ongoing UNILAC (Universal Linear Accelerator) upgrade program, a new uranium beam intensity record (10 emA, U29+) at very high beam brilliance was achieved last year in a machine experiment campaign at GSI. The UNILAC as well as the heavy ion synchrotron SIS18 will serve as a high current heavy ion injector for the new FAIR (Facility for Antiproton and Ion Research) synchrotron SIS100. Results of the accomplished high current uranium beam measurements applying a newly developed pulsed hydrogen gas stripper (at 1.4 MeV/u) will be presented. The paper will focus on the evaluation and analysis of the measured beam brilliance and further implications to fulfil the FAIR heavy ion high intensity beam requirements.

Commissioning and Operations, Tuesday, 2016 July 5, 14:00-18:00

TUPM1Y01 **Advances in the Development of the ESS-Bilbao Proton Injector**

Zunbeltz Izaola, Ibon Bustinduy, Carlos de la Cruz, Giles Harper, Rosalba Miracoli, Juan Luis Munoz, Igor Rueda (ESS Bilbao, Zamudio), Javier Corres, Aitor Zugazaga (ESS Bilbao, Derio), David de Cos, Alvaro Vizcaino (ESS Bilbao, LEIOA)

We present the last advances in the operation and construction of the ESS-Bilbao 3 MeV proton beam injector. The proton ECR source allows to change the distance between the plasma chamber and the first extraction electrode, acceleration gap. The beam has been characterised at different acceleration gaps by current transformers, wire scanners and photographs of 2d profiles. In addition, we present the status of the construction of the RFQ; which is at its beginning.

TUPM2Y01 **Beam Commissioning Results for the CSNS MEBT and DTL-1**

Jun Peng, mingtao li (CSNS, Guangdong Province), Yuwen An, Shinian Fu, Ming-Yang Huang, Yong Li, Zhiping Li, Yudong Liu, Sheng Wang, Shou Yan Xu, Yue Yuan (IHEP, Beijing)

The China Spallation Neutron Source(CSNS) will deliver a 100kW proton beam with capacity of being updated to 500kW to a solid metal target for neutron scattering research. The accelerator complex consists of a 50keV H- ion source, a 3MeV Radio Frequency Quadrupole(RFQ), a 80MeV Drift tube Linac(DTL), and a 1.6GeV rapid-cycling synchrotron(RCS). The front end and the first tank of DTL were fully characterized since July 2016, using a temporal diagnostic beam line. This paper reports on the strategy and the results of the commissioning.

TUPM3Y01 **Operational Experience and Future Plans at ISIS**

Dean Adams (STFC/RAL/ASTeC, Chilton, Didcot, Oxon)

The ISIS spallation neutron and muon source has been in operation since 1984. The accelerator complex consists of an H- ion source, 665 keV RFQ, 70 MeV linac, 800 MeV proton synchrotron and associated beam transfer lines. The facility currently delivers 2.8E13 protons per pulse (ppp) at 50 Hz, which is shared between two target stations. High intensity performance and operation are dominated by the need to minimise and control beam loss, which is key to sustainable machine operation, allowing essential hands on maintenance. The facility has had several upgrades including an RFQ, ring Second Harmonic RF system, key developments of diagnostics and instrumentation required for improving beam control and a Second Target station. Upgrades being installed, or expected in the near future, include: a ring damping system, a new injector MEBT with fast injection chopper and an upgraded 50 Hz target. Operational experience of ISIS and the impacts of its past and future upgrades are discussed. Ideas for major upgrades to ISIS are briefly reviewed, as are the underlying R&D projects.

TUPM4Y01 **IFMIF-EVEDA RFQ, Measurement of Beam Input Conditions and Preparation to Beam Commissioning**

Michele Comunian, Enrico Fagotti, Andrea Pisent (INFN/LNL, Legnaro (PD)), Luca Bellan (INFN/LNL, Legnaro (PD); Univ. degli Studi di Padova, Padova)

The commissioning phase of the IFMIF-EVEDA RFQ requires a complete beam characterization with simulations and measurements of the beam input from the IFMIF-EVEDA ion source and LEBT, in order to reach the RFQ input beam parameters. In this article the simulations of source LEBT RFQ will be reported with the corresponding set of measurements done on the Ion source and LEBT.

TUPM5Y01 **ESS Linac Plans for Commissioning and Initial Operations**

Ryoichi Miyamoto, Mohammad Eshraqi, Marc Munoz (ESS, Lund)

Beam commissioning of the proton linac of the European Spallation Source (ESS) is planned to be conducted in 2018 and 2019. At this stage, the last 21 cryomodules are not yet installed and the maximum beam energy and power are 570 MeV and 1.4 MW, with respect to the nominal 2 GeV and 5 MW. The linac will be operated in this condition until the remaining cyromodules are installed in two stages in 2021 and 2022. On top of the common challenges of beam dynamics and machine protection, commissioning of a large scale machine, such as the ESS linac within a relatively short integrated time of less than 40 weeks imposes an additional challenge to the scheduling and planning. This paper lays out the current plans of the ESS linac for its beam commissioning as well as the initial operation.

TUPM6Y01 **Commissioning of C-ADS Injector I**

Jianshe Cao, Huiping Geng, Rong Liu, Cai Meng, Fang Yan, Qiang Ye (IHEP, Beijing), Yanfeng Sui (IHEP,)

As a test facility, the design goal of C-ADS Injector I is a 10mA, 10MeV CW proton linac, which uses a 3.2MeV normal conducting RFQ and superconducting single-spoke cavities for accelerating. The RF frequency of C-ADS Injector I accelerator is 325 MHz. In accordance to the progress of construction and considering the technical difficulties, the beam commissioning of C-ADS Injector I is carried out in 3 phases: Phase 1, with ECRIS + LEBT + RFQ + MEBT + TCM (two superconducting cavities), to reach 3.6 MeV; Phase 2, with ECRIS + LEBT + RFQ + MEBT + CM1 (seven superconducting cavities), to reach 5 MeV; Phase 3, with ECRIS + LEBT + RFQ + MEBT + CM1+ CM2 (same as CM1), to finally achieve the design goal of C-ADS Injector I. This paper summarizes the beam commissioning in 3 phases and focusing on the third phase.

TUPM7Y01 **SPIRAL 2 Commissioning Status**

Jean-Michel Lagniel (GANIL, Caen)

The first phase of the SPIRAL 2 project dealing with the high-power superconducting linac and the two experimental areas called Neutron for Science (NfS) and Super Separator Spectrometer (S3) is well advanced. The project has entered in a phase during which the linac components are successively installed and commissioned (the first beam was produced in December 2014). After having briefly recalled the project scope and parameters, the way the accelerator installation and commissioning are done is presented.

TUPM8Y01 **Lessons of High-power CW Beam Commissioning of Injector II of Chinese ADS**

Huan Jia (IMP/CAS, Lanzhou)

The Chinese ADS Injector II has commissioned CW proton beam to 4.6 MeV, 3.9 mA with superconducting linac. Lessons of high-power beam commissioning, including lattice settings, phase scan, power ramping procedure and accidents will be presented.

TUPM9Y01 **Observations of Coupling During Accumulation Using a Non-Destructiv**
Electron Scanner in the Spallation Neutron Source Accumulator Ring
Robert Edward Potts (ORNL RAD, Oak Ridge, Tennessee), Willem Blokland, Sarah M. Cousineau, Jeffrey Alan Holmes (ORNL, Oak Ridge, Tennessee)
An electron scanner has been installed in the accumulator ring of the Spallation Neutron Source (SNS). The non-destructive device permits turn-by-turn measurements of the horizontal and vertical profiles of the proton beam during accumulation with fine longitudinal resolution. In this study the device is used to identify the source of transverse coupling in the SNS ring and to understand the impact of space charge on the evolution of the coupled beam. We present experimental observations of coupling dependent on tune, injected intensity, and accumulated intensity for a simplified accumulation scenario with no RF and no injection painting. We also investigate the effects of varying the skew quadrupoles and tune for beams with the SNS production-style ring injection and ring RF patterns.

7.6 Wednesday

Beam Dynamics in Rings, Wednesday, 2016 July 6, 9:00-12:40

WEAM1X01 **Code Benchmarking for Long-Term Tracking and Adaptive Algorithms**

Frank Schmidt (CERN, Geneva)

At CERN we have ramped up a program to investigate space charge effects in the LHC pre-injectors with high brightness beams and long storage times. This in view of the LIU upgrade project for these accelerators. These studies require massive simulation over large number of turns. To this end we have been looking at all available codes and started collaborations on code development with several laboratories: pyORBIT from SNS, SYNERGIA from Fermilab, MICROMAP from GSI and our in-house MAD-X code with an space charge upgrade. We have agreed with our collaborators to bench-mark all these codes in the framework of the GSI bench-marking suite, in particular the main types of frozen space charge and PIC codes are being tested. We also include a study on the subclass of purely frozen and the adaptive frozen modes both part of MAD-X in comparison with the purely frozen MICROMAP code. Last, we will report on CERN's code development effort to understand and eventually overcome the noise issue in PIC codes.

WEAM2X01 **PIC Solvers for Intense Beams: Status and Future Prospects**

Oliver Boine-Frankenheim (GSI, Darmstadt)

Particle tracking codes employing Particle-In-Cell (PIC) techniques for the space charge forces are the standard tool for studies of incoherent and coherent effects in intense beams. The numerical noise inherent to the PIC scheme is a concern for accurate predictions of emittance growth and beam loss in synchrotrons and accumulator rings for high intensity. The predictions require long-term simulation including space charge forces obtained self-consistently. Besides the noise reduction, for long-term accuracy particle tracking schemes should also be symplectic. A novel class of multi-symplectic PIC integrators, originally developed for applications in plasma physics, promises bounded phase space motion together with noise reduction. For illustration a 2d symplectic space charge algorithm will be introduced and applied to a beam in a simple periodic focusing structure. The obtained noise characteristic, numerical emittance growth and performance will be compared to standard PIC schemes. Possible directions for future developments will be outlined.

WEAM3X01 **Code Development for Collective Effects**

Kevin Shing Bruce Li, Hannes Bartosik, Giovanni Iadarola, Andrea Passarelli, Annalisa Romano, Giovanni Rumolo (CERN, Geneva), Adrian Oeftiger, Michael Schenk (CERN, Geneva; EPFL, Lausanne), Stefan Hegglin (ETH, Zurich)

The presentation will cover approaches and strategies of modeling and implementing collective effects in modern simulation codes. We will review some of the general approaches to numerically model collective beam dynamics in circular accelerators. We will then look into modern ways of implementing collective effects with a focus on plainness, modularity and flexibility, using the example of the PyHEADTAIL framework, and highlight some of the advantages and drawbacks emerging from this method. To ameliorate one of the main drawbacks, namely a potential loss of performance compared to the classical fully compiled codes, several options for speed improvements will be mentioned and discussed. Finally some examples and application will be shown together with future plans and perspectives.

WEAM4X01 **Numerical Modeling of Fast Beam Ion Instabilities**

Lotta Mether, Giovanni Rumolo (CERN, Geneva)

The fast beam ion instability may pose a risk to the operation of future electron accelerators with beams of high intensity and small emittances, including several structures of the proposed CLIC accelerator complex. Numerical models can be used to identify necessary vacuum specifications to suppress the instability, as well as requirements for a possible feedback system. Vacuum requirements imposed by the instability have previously been estimated for linear CLIC structures, using the strong-strong macro-particle simulation tool FASTION. Currently, efforts are being made to improve the simulation tools, and allow for equivalent studies of circular structures, such as the CLIC damping rings, on a multi-turn scale. In this contribution, we review the recent code developments, and present first simulation results.

WEAM5X01 **Beam-dynamics Issues in the FCC**

Frank Zimmermann (CERN, Geneva)

Profiting from strong synchrotron radiation damping, the FCC-hh collider will operate with proton and heavy-ion beams of unprecedented brightness. Limitations arise from single-beam collective effects, such as loss of Landau damping,and from the beam-beam collision, e.g. running at the beam-beam limit. Beam stabilization may require both transverse and longitudinal emittance control by noise excitation. The performance could be further boosted by novel techniques like electron lenses. The FCC-hh beam diagnostics will also enter a new regime for hadron machines.

WEAM6X01 **Studies of High Intensity Proton FFAGs at RAL**

Christopher Prior (STFC/RAL/ISIS, Chilton, Didcot, Oxon)

The paper describes studies of high intensity proton accelerators for a next-generation source of short-pulse spallation neutrons. Along with conventional designs using rapid cycling synchrotrons, the long-term nature of the project provides scope for novel accelerator designs and developing technological ideas. A range of FFAG options is under consideration for the main spallation driver. Theory and simulation in the UK are combined with experimental studies of FFAGs in Japan, and a small prototype FFAG ring is planned to go on the FETS injector at RAL for essential R&D. The paper covers the broad scope of the programme and details the success of the study to date.

WEAM7X01 **Nonlinear Focusing in IOTA for Space-Charge Compensation and Landau Damping**

Sergei Nagaitsev (Fermilab, Batavia, Illinois)

In 1967 Edwin McMillan proposed the first stable nonlinear accelerator focusing system (Report UCRL-17795). Since then, there have been several additional theoretical proposals on how to implement a practical nonlinear accelerator focusing system, but none were ever tested experimentally. This presentation will describe several practical proposals to implement nonlinear focusing elements in the Fermilab IOTA ring. These nonlinear elements would employ magnetic fields and electron lenses to create a large betatron tune spread and may help increase beam intensities in present and future accelerators, by providing space-charge compensation and increasing Landau damping.

WEAM8X01 **Two-plane Painting Injection in BRing of HIAF Project**

Weiping Chai (IMP/CAS, Lanzhou)

HIAF-BRing is a high intensity heavy ion booster ring in which the particle number is designed up to 1.0E11 (238U34+). In order to prevent the stored beam from being killed immediately by the electron-ion interaction (while accumulating with electron-cooling) and strong space charge effect, the incoming iLinac beam must be accumulated as fast as possible. The two-plane painting injection is consequently adopted. In this talk, the detailed mechanism of the two-plane painting injection is shown, the orbit design and simulation is performed, and the injection parameters are optimized according to the simulation results using PSO (particle swarm optimization) algorism.

Beam Instruments and Interactions, Wednesday, 2016 July 6, 14:00-18:00

WEPM1X01 **Performance of Linac-4 Instrumentation during Commissioning**

Uli Raich (CERN, Geneva)

Linac-4 is CERNŠs new H- Linac, which will replace the aging Linac-2 proton machine. Linac-4 is being built and commissioned in stages. While the machine is permanently equipped with the standard beam instrumentation necessary to ensure smooth operation, three dedicated measurement benches have also been designed to commission the source and LEBT at 45 keV, the MEBT and its chopper at 3 MeV as well as the first DTL tank at 12 MeV and finally the full DTL at 50 MeV and CCDTL at 100 MeV. The beam after the PIMS structures at the LinacŠs full energy of 160 MeV will be sent to a beam dump and commissioned with permanently installed instruments. Installation and commissioning of the machine up to the CCDTL is now complete. This contribution will present the results from the various commissioning stages, showing the performance of the various diagnostic devices used and comparing the data obtained to simulations.

WEPM2X01 **High Power Target Instrumentation at J-PARC for Neutron and Muon Sources**

Shin-ichiro Meigo, Masaaki Nishikawa (JAEA/J-PARC, Tokai-Mura, Naka-Gun, Ibaraki-Ken), Tomoyuki Kawasaki, Motoki Ooi (JAEA/J-PARC, Tokai-mura), Hiroshi Fujimori, Shin-pei Fukuta (KEK/JAEA, Ibaraki-Ken)

At the J-PARC, spallation neutron and muon sources are injected 3-GeV proton beam with power of 1 MW extracted from 25 Hz Rapid Cycling Synchrotron (RCS). Recently several shots of the beam with equivalent power of 1 MW were successfully delivered to the targets without significant beam loss. Since the pitting erosion on the mercury target vessel utilized for spallation neutron source is known to be proportional to the 4th power of the beam current density, peak current density at the target should be kept as low as possible so that we have developed beam-flattening system by nonlinear beam optics using octupole magnets. To carry out the beam tuning efficiently, beam-tuning tool had been developed by using SAD code system. It is found that the shape of the beam can be controlled as designed. By using anti-correlated painting at the injection of the RCS, the beam was found to be shaped more flat distribution. The peak current density at the target can be reduced by 30 % with the present nonlinear optics without significant beam loss around at octupole magnets, which mitigates 76 % of the damage at the target vessel.

WEPM3X01 **Developments in High-Precision Fast Wire Scanners for High Intensity Proton Accelerators**

Bernd Dehning (CERN, Geneva)

Wire scanners are the preferred proton beam profile measurement instruments. The scanner profile width measurement accuracy is unsurpassed and the scanners are applicable for a large beam intensity range. The transverse beam profile is sampled by the movement of a thin wire through the beam measuring impacting beam intensity and wire position. The equipment challenges are in the accurate measurement of the wire position during the high speed scan. The scan speed is maximized to cope with high intensity proton beams by limiting the energy deposition in the wire. In the contribution the operational scanner designs will be presented and their limits will be discussed. Novel approaches to overcome some limitations will be presented as well.

WEPM5X01 **LHC Collimation for the Run Ii and Beyond**

Stefano Redaelli (CERN, Geneva)

The LHC achieved in 2015 record stored beam energies of about 280MJ with 6.5TeV proton beams, surpassing by about 2 orders of magnitudes achieved in previous superconducting colliders. The LHC collimation system played a key role in this achievement, ensuring a safe operation well below quench limits of superconducting magnets. In this paper, the collimation system for the LHC Run II is presented. Accelerator physics and operational challenges for controlling LHC beam losses are discussed and the collimation performance is reviewed. Limitations of the system and requirements for operating the LHC beyond Run II are also reviewed.

WEPM6X01 **Beam Halo Collimation Over Wide Range Charge-to-Mass Ratio**

Ivan Strasik (GSI, Darmstadt), Oliver Boine-Frankenheim (GSI, Darmstadt; TEMF, TU Darmstadt, Darmstadt)

We present a study of the halo collimation of ion beams from proton up to uranium in the projected FAIR heavy ion synchrotron SIS100. The design concepts are separated into fully stripped and partially stripped ion collimation. An application of the two stage betatron collimation system is intended for fully stripped ions and protons. Interaction of the particles with the primary collimator material was simulated using FLUKA. Particle tracking simulations and beam loss maps were obtained using MAD-X. The concept for the collimation of partially stripped ions is based on a stripping foil in order to change their charge state. These ions are subsequently deflected towards collimators using a quadrupole magnetic field. The charge state distribution of the stripped ions was calculated using GLOBAL. The particle tracking simulations downstream of the foil were performed using MAD-X. Inelastic nuclear interaction and consequently hadronic fragmentation and electromagnetic dissociation of heavy ions were simulated using FLUKA. The fragments with a significant abundance were tracked through the accelerator lattice and their contribution to the overall beam loss distribution was estimated.

WEPM7X01 **The Application of the Optimization Algorithm in the Collimation System for CSNS/RCS**

Hongfei Ji, Ming-Yang Huang, Yi Jiao, Na Wang, Sheng Wang, Shou Yan Xu (IHEP, Beijing)

The robust conjugate direction search (RCDS) method, which is developed by X. Huang from the SLAC National Accelerator Laboratory, has high tolerance against noise in beam experiments and thus can find an optimal solution effectively and efficiently. In this paper, the RCDS method is used to optimize the beam collimation system for Rapid Cycling Synchrotron (RCS) of the China Spallation Neutron Source (CSNS). A two-stage beam collimation system was designed to localize the beam loss in the collimation section in CSNS/RCS. The parameters of secondary collimators are optimized with RCDS algorithm based on detailed tracking with the ORBIT program for a better performance of the collimation system. The study presents a way to quickly find an optimal parameter combination of the secondary collimators for a machine model for preparation for CSNS/RCS commissioning.

WEPM8X01 **Collimation Design and Beam Loss Detection at FRIB**

Zhengzheng Liu, Masanori Ikegami, Steven Michael Lidia, Felix Marti (FRIB, East Lansing, Michigan), Vera Chetvertkova (GSI, Darmstadt), Tomofumi Maruta (KEK/JAEA, Ibaraki-Ken)

As a multi-charge-state, heavy-ion, superconducting accelerator with a folded geometry, FRIB faces unique beam loss detection and collimation challenges to protect superconducting cavities from beam-induced damage. Collimation is especially important in the region following the charge stripper, where multiple charge states are transported and interaction with the residual gas could induced significant beam losses. We have simulated the potential beam losses and planned collimation accordingly. FRIBŠs double-folded geometry presents difficulties to a conventional beam loss detection network. We have designed a layered loss detection network specifically to visualize potential blind zones and to meet the stringent requirements on loss detection. We continue to conduct loss simulations and fault studies to optimize the loss detection network and collimator design.

WEAM1Y01 **A coupled RFQ-IH-DTL Cavity for FRANZ: A Challenge for RF Technology and Beam Dynamics**

Rudolf Tiede, Oliver Meusel, Holger Podlech, Ulrich Ratzinger, Alwin Schempp, Malte Schwarz, Christoph Wiesner [on leave] (IAP, Frankfurt am Main), Dominik MŁder (BEVATECH, Frankfurt), Manuel Heilmann (GSI, Darmstadt)

For the 'Frankfurt Neutron Source at the Stern-Gerlach-Zentrum' (FRANZ) facility an inductively coupled combination of a 4-rod radio-frequency-quadrupole (RFQ) and an 8 gap interdigital H-type (IH-DTL) structure will provide the main acceleration of an intense proton beam from 120 keV to 2.0 MeV. The RFQ-IH combination with a total length of about 2.3 m will be operated at 175 MHz in cw mode. The expected total power need is around 200 kW. Due to the internal inductive coupling only one RF amplifier is needed, which significantly reduces the investment costs. At present the RFQ is installed separately in the beam line for conditioning up to the design rf power and for measuring the beam quality behind the RFQ. In parallel, the IH-DTL is rf tuned together with a dummy RFQ outside the FRANZ cave. This paper will present the status of the project with emphasis on key questions like beam dynamics constraints, rf tuning issues and technological challenges resulting from the high thermal load in cw operation.

WEAM2Y01 **Overview of the CSNS Linac LLRF and Operational Experiences During Beam Commissioning**

Zhencheng Mu (IHEP, Beijing), Jian Li, Mei Fei Liu, Lin Yan Rong, Ma Liang Wan, Bo Wang, Zhe Xin Xie, Xin An Xu, Yuan Yao, Zonghua Zhang, Wenzhong Zhou (CSNS, Guangdong Province)

The CSNS Linac is comprised of RFQ, two Buncher cavities, four DTL accelerators and one Debuncher cavity. The RFQ accelerator is powered by two 4616 vacuum tubes, the maximum output power of each tube is 350kW. Three 25kW solid state amplifiers supply RF power for two Buncher cavities and the Debuncher cavity, repectively. The RF power sources of four DTL accelerators are four 3MW klystrons. Each RF power source owns a set of digital LLRF control system in order to realize an accelerating field stability of $\pm$1% in amplitude and $\pm$1ą in phase. The front four LLRF control systems have been used in the beam commissioning of CSNS Linac from the end of 2015. This paper will introduce the design and the performance of the LLRF control system.

WEAM3Y01 **Present Status of the High Current Linac at Tsinghua University and Its Applications**

Qingzi Xing, Du Tai Bin, Cheng Cheng, Changtong Du, Lei Du, Xialing Guan, Chuanxiang Tang, Ruo Tang, Xuewu Wang, Huayi Zhang, Qingzhu Zhang, Shuxin Zheng (TUB, Beijing), Weiqiang Guan, Yu He, Jian Li (NUCTECH, Beijing)

The CPHS (Compact Pulsed Hadron Source) linac at Tsinghua University, is now in operation as an achievement of its mid-term objective. The RFQ accelerator was operated stably with the beam energy of 3 MeV, peak current of 26 mA, pulse length of 100 μs and repetition rate of 20 Hz. After the maintenance phase the transmission rate of the RFQ accelerator has been recovered from 65% to 91%. The beam emittance and 2D profiles are measured and compared with the simulation result.

WEAM4Y01 **Design and prototyping of the Spoke Cyromodule for ESS**

Patxi Duthil, Sébastien Bousson, Sylvain Brault, Patricia Duchesne, Nicolas Gandolfo, Guillaume Olry, Matthieu Pierens, Emmanuel Rampnoux, Denis Reynet (IPN, Orsay), Christine Darve (ESS, Lund)

A cryomodule integrating two superconducting radiofrequency (SRF) double Spoke cavities and their RF power couplers is now being assembled at IPNO. It is the prototype version of the 13 future cryomodules composing a 56 meters long double Spoke section which will be operated for the first time in a linear accelerator (linac) for the European Spallation Source (ESS). ESS will be the most powerful neutron source feeding multidisplinary researches. This cryomodule provides the cryogenic environment for operating the two β=0.5 cavities at full power in a saturated superfluid helium bath at a temperature of 2 K. Thermally and magnetically shielded, they will each be fed by a 352 MHz electromagnetic wave, with a peak power of 400 kW, to generate an accelerating pulsed field of 9MV/m. For this operation, the prototype cryomodules includes all the interfaces with RF, cryogenics, vacuum, beam pipe and diagnostics. It will be tested by 2016 at IPNO by use of a test valve box which is also a prototype of the future Spoke cryogenic distribution system, another contribution to ESS. Both prototypes will then be tested at full power at Uppsala university FREIA facilities.

WEAM5Y01 **Study of Analyzing and Matching of Mixed High Intensity Highly Charged Heavy Ion Beams**

Xiaohu Zhang, Liangting Sun, Yao Yang, Xuejun Yin, Youjin Yuan, Hongwei Zhao (IMP/CAS, Lanzhou)

Electron cyclotron resonance (ECR) ion sources are widely used in heavy ion accelerators for their advantages in producing high quality intense beams of highly charged ions. However, it exists challenges in the design of the Q/A selection systems for mixed high intensity ion beams to reach sufficient Q/A resolution while controlling the beam emittance growth. Moreover, as the emittance of beam from ECR ion sources is coupled, the matching of phase space to post accelerator, for a wide range of ion beam species with different intensities, should be carefully studied. In this paper, the simulation and experiment performances of Q/A selection system at the LECR4 platform are shown. The formation of hollow cross section heavy ion beam at the end of the Q/A selector is revealed. A reasonable interpretation has been proposed, an updating design of Q/A selection system has been committed for HIRFL-SSC linac injector. The features of the new design including beam simulations and experiment results are also presented.

WEAM6Y01 **R&D on Crab Cavities for the HL-LHC**

Rama Calaga (CERN, Geneva)

As a part of the HL-LHC upgrade significant R&D has taken place on compact superconducting crab cavities. Their implementation in high energy proton collider will be the first of its kind including the initial phase of technology validation in the SPS. This paper will primarily focus on the recent progress on the cavity and cryomodule developments and some of the main challenges. A few aspects related to the impact of crab cavities on the LHC beams are also addressed.

WEAM7Y01 **The Beam Delivery System of the European Spallation Source**

Heine Dølrath Thomsen (Aarhus University, Aarhus), Søren Pape Møller (ISA, Aarhus)

The European Spallation Source (ESS) will apply a fast beam scanning system to redistribute the proton beam transversely across the spallation target surface. The system operates at sweep frequencies of tens of kHz and efficiently evens out the time-averaged beam intensity within a nominal beam footprint, thus reducing the level of beam-induced material damage. A modular design approach divides the raster action in each direction across 4 independent magnet-supply systems to distribute the magnetic load, ease the peak output power per modulator, and in general reduce the amount of single points of failure. The state of the magnet design and power supply topology will be discussed.

Beam Dynamics in Linacs, Wednesday, 2016 July 6, 14:00-18:00

WEPM1Y01 **Emittance Reconstruction Techniques in Presence of Space Charge Applied During the Linac4 Beam Commissioning**

Veliko Atanasov Dimov, Jean-Baptiste Lallement, Alessandra Maria Lombardi (CERN, Geneva), Rahul Gaur (RRCAT, Indore)

The classical emittance reconstruction technique, based on analytic calculations using transfer matrices and beam profile measurements, is reliable only if the emittance is conserved and the space charge forces are negligible in the beamline between the reconstruction and measurement points. The effects of space charge forces prevent this method from giving sound results up to a relativistic beta of about 0.5 and make it inapplicable to the Linac4 commissioning at 50 and 100 MeV. To compensate for this drawback we have developed a dedicated technique, the forward method, which extends the classical method by combining it with an iterative process of multiparticle tracking including space charge forces. The forward method, complemented with a tomographic reconstruction routine, has been applied to transverse and longitudinal emittance reconstruction during the Linac4 beam commissioning. In this paper we describe the reconstruction process and its application during Linac4 beam commissioning.

WEPM2Y01 **Model Benchmark With Experiment at SNS Linac**

Andrei P. Shishlo, Alexander V. Aleksandrov, Michael Plum (ORNL, Oak Ridge, Tennessee), Yun Liu (ORNL RAD, Oak Ridge, Tennessee)

The history of attempts to perform a transverse matching in the SNS superconducting linac (SCL) is discussed. The SCL has 9 laser wire (LW) stations to perform nondestructive measurements of the transverse beam profiles. Any matching starts with the measurement of the initial Twiss parameters which in the SNS case was done by using the first four LW stations at the beginning of the superconducting linac. For years the consistency between all LW stations data could not be achieved. This problem was resolved only after significant improvements in accuracy of the phase scans of the SCL cavities, more precise analysis of all available scan data, better optics planning, and the initial longitudinal Twiss parameters measurements. The presented paper discusses in details these developed procedures.

WEPM3Y01 **Efficient Particle In Cell Simulations of Beam Collimation in the FRIB Front-End**

Steven Mocko Lund, Kei Fukushima (FRIB, East Lansing, Michigan), Chun Yan Jonathan Wong (NSCL, East Lansing, Michigan)

Particle-In-Cell (PIC) simulations of FRIB front-end are being carried out with the open-source Warp code. Near source evolution of an intense, multi-species DC ion beam emerging from a Electron Cyclotron Resonance (ECR) source is simulated in a realistic lattice. Flexible, script-based simulation tools are applied to analyze the plethora of ion cases within a maintainable and extendable framework to support front-end commissioning activities which commence in late 2016. Linked transverse xy slice and 3D simulations are carried out in the lattice downstream of the ECR to better understand species charge selection and collimation. The simulations improve understanding of the complex dynamics and augment limited laboratory diagnostics to improve optimization. Effects from large canonical angular momentum (magnetized beam from ECR) induced beam rotation, thermal spread, initial distribution asymmetries, space-charge, and varying degree of electron neutralization are examined for impact on charge selection and beam quality. Ranges of initial conditions are analyzed since the beam emerging from ECR sources is not well understood. Simulation scripts developed are made freely available.

WEPM4Y01 **HPSim - Advanced Online Modeling for Proton Linacs**

Lawrence Rybarcyk (LANL, Los Alamos, New Mexico)

High-power proton linacs seek to operate with low and stable losses. This aspect is carefully evaluated with multi-particle beam dynamics codes during the design stage. However, it is just as important to evaluate the performance of the actual operating linac, which is typically more tedious and complicated when using these same design codes. To improve this situation, we have developed a high-performance, multi-particle online modeling tool, HPSim, with the goal of providing near real-time simulation results for our 800-MeV proton linac at Los Alamos. This presentation will cover the motivation, code features, benefits and applications.

WEPM5Y01 **H- Beam Dynamics Study of a LEBT in XiPAF Project with the WARP PIC Code**

Tang Ruo, Lei Du, Taibin Du, Xialing Guan, Chuanxiang Tang, Xuewu Wang, Qingzi Xing, Huayi Zhang, Qingzhu Zhang (TUB, Beijing), Weiqiang Guan, Yu He, Jian Li (NUCTECH, Beijing)

The 7MeV H- linac injector of Xi'an Proton Application Facility (XiPAF) is composed of an ECR ion source, a Low Energy Beam Transport line (LEBT), a Radio Frequency Quadrupole accelerator (RFQ) and a Drift Tube Linac (DTL). The 1.7m-long LEBT is used for matching a 40μs pulse width 6mA peak current beam to the RFQ entrance. The peak current and pulse-width of the 50keV H- beam extracted from the ion source is 10mA and 1ms. In the LEBT, an adjustable square aperture is used for scraping the beam's peak current into 6mA, and an electric chopper is used for chopping the beam's pulse width into 40μs. These two elements make the space charge compensation problem more complicated. A careful simulation of the H- beam space charge compensation problem has been done by considering the beam particles interacting with the residual gas in the LEBT's vacuum pipe. This paper shows the detail simulation of the H- beam dynamics with the WARP PIC code.

WEPM6Y01 **Study on Space Charge Compensation of Low Energy High Intensity Ion Beam in Peking University**

ShiXiang Peng, Zhiyu Guo, Jiamei Wen, Wenbin Wu, Yuan Xu, Jingfeng Zhang, Tao Zhang (PKU, Beijing), Haitao Ren (FRIB, East Lansing, Michigan; PKU, Beijing), Jia-er Chen (Graduate University, Beijing; PKU, Beijing), Ailin Zhang (PKU, Beijing; University of Chinese Academy of Sciences, Beijing)

To better understand the space charge compensation processes in low energy high intensity beam transportation, numerical study and experimental simulation on H+ beam and H- beam were carried out at Peking University (PKU). The numerical simulation is done with a PIC-MCC model [1] whose computing framework was done with the 3D MATLAB PIC code bender [2], and the impacts among particles were done with Monte Carlo collision via null-collision method [3]. Issues, such as beam loss caused by collisions in H+, H- beam and ion-electron instability related to decompensation and overcompensation in H- beam, are carefully treated in this model. The experiments were performed on PKU ion source test bench. Compensation gases were injected directly into the beam transportation region to modify the space charge compensation degree. The results obtained during the experiment are agree well with the numerical simulation ones for both H+ beam [1] and H- beam [4]. Details will be presented in this paper.

WEPM7Y01 **Transverse Coupling Property of Beam From ECR Ion Sources**

Yao Yang (IMP/CAS, Lanzhou)

Experimental evidence of the property of transverse coupling of beam from Electron Cyclotron Resonance (ECR) ion source is presented. It is especially of interest for an ECR ion source, where the cross section of extracted beam is not round along transport path due to the magnetic confinement configuration. When the ions are extracted and accelerated through the descending axial magnetic field at the extraction region, the horizontal and vertical phase space strongly coupled. In this study, the coupling configuration between the transverse phase spaces of the beam from ECR ion source is achieved by beam back-tracking simulation based on the measurements. The reasonability of this coupling configuration has been proven by a series of subsequent simulations. Based on this study, an improved operation scheme for the SFC injector line at IMP has been proposed to reduce the projection emittances by beam decoupling. Preliminary test has verified this proposal.

WEPM8Y01 **Simulation of Space-Charge Compensation of a Low-Energy Proton Beam in a Drift Section**

Daniel Noll, Martin Droba, Oliver Meusel, Ulrich Ratzinger, Kathrin Schulte (IAP, Frankfurt am Main)

Space-charge compensation provided by the accumulation of particles of opposing charge in the beam potential is an important effect occuring in magnetostatic low energy beam transport sections of high-intensity accelerators. An improved understanding of its effects might provide valuable input for the design of these beam lines. One approach to model the compensation process are Particle-in-Cell (PIC) simulations including residual gas ionisation. In simulations of a drifting proton beam, using the PIC code bender [1], some features of thermal equilibrium for the compensation electrons were found. This makes it possible to predict their spatial distribution using the Poisson-Boltzmann equation and thus the influence on beam transport. In this contribution, we will provide a comparison between the PIC simulations and the model as well as some ideas concerning the source the (partial) thermalization.

7.7 Thursday

Commissioning and Operations, Thursday, 2016 July 7, 9:00-12:40

THAM1X01 **Reuse Recycler: High Intensity Proton Stacking at Fermilab**

Philip Adamson (Fermilab, Batavia, Illinois)

After a successful career as an antiproton storage and cooling ring, Recycler has been converted to a high intensity proton stacker for the Main Injector. We discuss the commissioning and operation of the Recycler in this new role, and the progress towards the 700 kW design goal.

THAM2X01 **Operational Experience at KOMAC**

Yong-Sub Cho (Korea Atomic Energy Research Institute (KAERI), Gyeongbuk)

A 100-MeV proton linac at the KOMAC (Korea Multi-purpose Accelerator Complex) is composed of a 50-keV microwave ion source, a 3-MeV four-vane-type RFQ, a 100-MeV DTL and 10 target stations for proton irradiation on samples from many application fields. The linac was commissioned in 2013 and the user service started in July 2013 with delivering proton beam to two target stations: one for a 20-MeV beam and the other for a 100-MeV beam. In 2015, the linac has been operated more than 2,800 hours with an availability of greater than 89%. The unscheduled downtime was about 73 hours, mainly due to problems of ion source arcing and failures of pulsed high-voltage power system. More than 2,100 samples from various fields such as materials science, bio-life and nano technology and nuclear science, were treated in 2015. Currently, a new target station for radioisotope production is under commissioning and a new target station for low-flux irradiation experiments is being installed. Operational experiences of the 100-MeV linac during the past 3 years will be presented in the workshop.

THAM3X01 **SNS Commissioning and Operations, the first 10 Years. An Overview of the Components Status after High Intensity Beam Operating Experience**

George W. Dodson (ORNL, Oak Ridge, Tennessee)

The SNS began commissioning of the entire accelerator, with beam to target, ten years ago in April 2006. Since then significant improvements we have made which have resulted in reduced beam loss and increased availability and beam power on target. The SNS accelerator systems have operated recently for significant periods of time at about 1.4MW with greater than 90% availability. Component status, improvements and operating experience will be presented.

THAM4X01 **Investigation to Improve Efficiency and Availability in Control and Operation of Superconducting Cavity at ESS**

Rihua Zeng (ESS, Lund), Olof Troeng (Lund University, Lund)

The higher efficiency and higher availability (fault-tolerant oriented) of RF&Cavity system (with beam loading) to operate at, the more dynamic details needs to be identified, so as to have the abilities (a) to work at nonlinearities, (b) to work close to limitation, and (c) to change operation point quickly and correctly. Dynamic detail identifications rely heavily on high precision measuring and characterizing basic cavity parameters (Ql, R/Q, dynamic detuning, phase and amplitude) and system behaviours under beam-RF-cavity interactions. It is especially challenging to characterize these dynamics under varying operating points or environment. Advanced technologies in LLRF and ICS providing real time/online characterizing will be the key enablers for addressing such challenges. However, to be successful, the deployment of these technologies must be embedded within local conditions taking into account available resources, existing hardware/software structures and operation modes. Several improvement approaches will be introduced. For example, 15% or more energy efficiency improvement at ESS will be obtained by reduction of power overhead and optimization of operation.

THAM5X01 **Lessons from LHC Commissioning**

Mike Lamont (CERN, Geneva)

Although not without some setbacks, LHC commissioning progressed relatively smoothly and led into a period of productive exploitation. This despite its complexity, the large scale use of superconductivity, and the attendant machine protection risks from stored magnetic and beam energy. The commissioning history is recalled. An attempt is made to extract possible elements of the general approach that might useful in a wider context.

THAM6X01 **The Path to 1 MW Ű Beam Loss Control in the J-PARC 3-GeV RCS**

Hideaki Hotchi (JAEA/J-PARC, Tokai-Mura, Naka-Gun, Ibaraki-Ken)

The J-PARC 3-GeV RCS started 1-MW beam test from October 2014, and successfully achieved a 1-MW beam acceleration in January 2015. The most important issues in realizing such a high power routine beam operation are control and minimization of beam loss. This talk will present the recent progress of 1-MW beam tuning, especially focusing on our approaches to beam loss issues.

THAM7X01 **RHIC Operation and e-lens Commissioning**

Xiaofeng Gu, James Alessi, Zeynep Altinbas, Edward Beebe, Michael Blaskiewicz, Joseph Michael Brennan, Donald Bruno, Michael Costanzo, Wolfram Fischer, Chris J. Gardner, David Gassner, Jon Hock, Haixin Huang, Peter Ingrassia, James Jamilkowski, Takeshi Kanesue, Chuyu Liu, Yun Luo, Gregory James Marr, Al Marusic, Chaofeng Mi, Robert Michnoff, Toby Allen Miller, Michiko Minty, Christoph Montag, Alexander I. Pikin, Vahid Houston Ranjbar, Deepak Raparia, Guillaume Robert-Demolaize, Thomas Roser, Theodoro Samms, Paul William Sampson, Vincent Schoefer, Travis Shrey, Kevin Smith, Yugang Tan, Steven Tepikian, Roberto Than, Peter Thieberger, Alex Zaltsman, Keith Zeno (BNL, Upton, Long Island, New York), Simon Mathieu White (ESRF, Grenoble)

In recent years the proton and ion beam intensity (as well as the current density) at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory improved considerably. Thanks to an upgrade of the polarized proton source we plan to increase the proton intensity to 3.0E11 per bunch. In order to accommodate the amplified beam-beam effect originating from proton beams with this unprecedented intensity, a beam-beam compensation scheme with a new lattice and two electron lenses (e-lenses) was installed, commissioned and began operation during the 2015 polarized 100 GeV proton Run.

THPM1X01 **Typology of space charge resonances**

Ingo Hofmann (GSI, Darmstadt)

Space charge has been discussed by a number of authors as important source of resonant or unstable behavior in high-intensity beams. In this paper we attempt to classify all possible modes leading to emittance growth according to their order and the type of driving mechanism. An important distinction is the origin of the driving space charge potential, which may be given by the initial distribution, or result from a process of instability, or a combination of both. The role of the initial distribution and the type of focusing lattice in this context are discussed.

THPM2X01 **Head-Tail Modes With Strong Space Charge: Theory and Simulations**

Alexey Burov (Fermilab, Batavia, Illinois)

Low and medium energy hadron circular machines are operating at a condition of the strong space charge, i.e. with the space charge tune shift much higher than the synchrotron tune. Theory of transverse instabilities developed by the author for such cases was recently checked in multiparticle tracking with the Synergia code, and a good agreement was demonstrated both for the modes structure and Landau damping rates. Main aspects of the theory will be reminded and the comparison results be demonstrated.

THPM3X01 **Head-Tail Instability and Landau Damping in Bunches with Space Charge**

Vladimir Kornilov, Oliver Boine-Frankenheim (GSI, Darmstadt)

Landau damping of the head-tail modes defines the impedance budget and the intensity limits for ring machine performance. The long-known source of the damping has been the octupole nonlinearity. So far, only the damping of the rigid mode k=0 has been modeled using a 2D dispersion relation. Recently, the transverse space-charge field has been identified as an important damping component. Quantitive estimations of the resulting Landau damping is still an open question, especially for the higher order modes. There is also a long-standing debate how to describe the head-tail frequency shifts due to coherent and due to incoherent effect in the stability calculations. We present a model for the Landau damping in bunches based on the concept of the collective mode positioning with respect to the incoherent spectrum. Secondly, we discuss an accurate description for the head-tail eigenfrequency shifts. The predictions and the physical understanding are verified using particle tracking simulations, and in particular by the experimental results.

THPM4X01 **Resonances and envelope instability in high intensity linear accelerators**

Dong-O Jeon, Ji-Ho Jang, Hyunchang Jin (IBS, Daejeon)

Understanding of space charge effects has grown and recent studies have led to the findings of resonances of high intensity linear accelerators. Lately the sixth order resonance of high intensity linear accelerators was reported, along with the in-depth studies on the fourth order resonance and the envelope instability. Experiment studies on space charge resonances were reported. This paper reviews the resonances of high intensity linear accelerators such as the 4sigma =360deg, and the 6sigma =720deg resonances, along with the envelope instability.

THPM5X01 **Using an Electron Cooler for Space Charge Compensation in the GSI Synchrotron SIS18**

William Stem (TEMF, TU Darmstadt, Darmstadt), Oliver Boine-Frankenheim (GSI, Darmstadt; TEMF, TU Darmstadt, Darmstadt)

For the future operation of the SIS18 as a booster synchrotron for the FAIR SIS100, space charge and beam lifetime are expected to be the main intensity limitations. Intensity is limited in part by the space-charge-induced incoherent tune shift in bunched beams. A co-propagating, low energy electron lens can compensate for this tune shift by applying opposing space-charge fields in the ion beam. In this talk, we study the effect of using the existing electron cooler at the SIS18 as a space charge compensation device. We anticipate beta beating may arise due to the singular localized focusing error, and explore the possibility of adding additional lenses to reduce this error. We also study the effect of electron lenses on the coherent (collective) and incoherent (single-particle) stopbands. Furthermore, we estimate the lifetime of partially stripped heavy-ions due to charge exchange process in the lens.

THPM6X01 **Space charge effects in FFAG**

Malek Haj Tahar, Francois Meot (BNL, Upton, Long Island, New York)

Understanding space charge effects in FFAG is crucial in order to assess their potential for high power applications. This paper shows that, to carry out parametric studies of these effects in FFAG, the average field index of the focusing and defocusing magnets are the natural parametrization. Using several classes of particle distribution functions, we investigate the effects of space charge forces on the non-linear beam dynamics of FFAG and provide stability diagrams for an FFAG-like lattice. The method developed in this study is mainly applicable to systems with slowly varying parameters.

THPM7X01 **Use of RF Quadrupole Structures to Enhance Stability in Accelerator Rings**

Michael Schenk, Alexej Grudiev, Kevin Shing Bruce Li, Kai Papke (CERN, Geneva)

The beams required for the high luminosity upgrade of the Large Hadron Collider (HL-LHC) at CERN call for efficient mechanisms to suppress transverse collective instabilities. In addition to octupole magnets installed for the purpose of Landau damping, we propose to use radio frequency (rf) quadrupole structures to considerably enhance the aforementioned stabilising effect. By means of the PyHEADTAIL macroparticle tracking code, the stabilising mechanism introduced by an rf quadrupole is studied and discussed. As a specific example, the performance of an rf quadrupole system in presence of magnetic octupoles is demonstrated for HL-LHC. Furthermore, potential performance limitations such as the excitation of synchro-betatron resonances are pointed out. Finally, efforts towards possible measurements with the CERN Super Proton Synchrotron (SPS) are discussed aiming at studying the underlying stabilising mechanisms experimentally.

THPM8X01 **Nonlinear Optics Experiments at the University of Maryland Electron Ring**

Kiersten J Ruisard, Brian Louis Beaudoin, Irving Haber, Timothy Koeth (UMD, College Park, Maryland)

Nonlinear quasi-integrable optics is a promising development on the horizon of high-intensity ring design. Large amplitude-dependent tune spreads, driven by strong nonlinear magnet inserts, lead to decoherence from incoherent tune resonances. This reduces intensity-driven beam loss while quasi-integrability ensures a well-contained beam. The nonlinear lattice also reduces halo growth due to fast decoherence of envelope modes. Experiments at the University of Maryland Electron Ring (UMER) test the performance of a strong octupole lattice at a range of operating points. We vary beam intensity to interrogate the interplay of the externally imposed tune spread with the space-charge tune spread. We vary lattice tune to change the quasi-integrable condition as well as probe behavior near different resonant conditions. We discuss the effect of steering errors on the lattice performance and on-going efforts to reduce these errors. Experiments to date use a distributed octupole lattice, consisting of several small octupole inserts. We also discuss plans for a single-channel insert design.

THPM9X01 **Space Charge Effects and Mitigation in the CERN PS Booster, in View of the Upgrade.**

Elena Benedetto (CERN, Geneva)

The CERN PS Booster (PSB) is presently running with a space-charge tune spread larger than 0.5 at injection. Since the High Luminosity LHC (HL-LHC) will require beams with twice the intensity and brightness of today, the LHC Injector Upgrade (LIU) Project is putting in place an upgrade program for all the injector chain and, in particular, it relies on the important assumption that the PS Booster can successfully produce these beams after the implementation of the 160 MeV H- injection from Linac4. This contribution describes the studies (measurements and simulations) that have been carried out to confirm that the PSB can indeed perform as needed in terms of beam brightness for the future HL-LHC runs. The importance of the mitigation measures already in place, such as the correction of the half-integer line, and the effects of non-linear resonances on the beam are also discussed.

THPM10X01 **Stripline Beam Position Monitors With Improved Frequency Response and Their Coupling Impedances**

Yoshihiro Shobuda (JAEA/J-PARC, Tokai-Mura, Naka-Gun, Ibaraki-Ken), Takeshi Toyama (J-PARC, KEK & JAEA, Ibaraki-ken), Yong Ho Chin, Koji Takata (KEK, Ibaraki), Keigo Nakamura (Kyoto University, Kyoto)

In J-PARC Main Ring, transverse intra-bunch oscillations have been observed during the injection and at the onset of acceleration. Up to now, the beam instability is suppressed by the intra-bunch feedback system, where the stripline beam position monitors operate at 108.8 MHz. However, there is a concern that electron cloud instabilities may appear and limit the beam current at future higher power operations. For the case, we have developed a wider-band (several GHz) beam position monitor by deforming the electrode shapes. The modification of the electrode can be done not to enhance the beam coupling impedance. For the typical electrode shapes, we show the coupling impedances as well as the frequency responses of the electrodes.

Beam Instruments and Interactions, Thursday, 2016 July 7, 9:00-12:40

THAM1Y01 **Beam Commissioning of C-ADS Linac Instrumentation**

Yanfeng Sui (IHEP,)

The China Accelerator Driven Subcritical system (C-ADS) linac, which is composed of an ECR ion source, a low energy beam transport line (LEBT), a radio frequency quadrupole accelerator (RFQ), a medium energy beam transport line (MEBT) and cryomodules with SRF cavities to boost the energy up to 10 MeV. The injector linac will be equipped with beam diagnostics to measure the beam position, the transverse profile and emittance, the beam phase as well as beam current and beam losses. Though many are conventional design, They can provide efficient operation of drive linac. This paper gives an overview and detail in beam commissioning of C-ADS linac beam instrumentation.

THAM2Y01 **Measurements of Beam Pulse Induced Mechanical Strain Inside the SNS* Target Module**

Willem Blokland, Yun Liu, Bernard Riemer, Mark Wendel, Drew Winder (ORNL, Oak Ridge, Tennessee), Michael Dayton (ORNL RAD, Oak Ridge, Tennessee)

Because several of the SNS targets have had a shorter lifetime than desired, a new target has been instrumented with strain sensors to further our understanding of the proton beamŠs mechanical impact. The extremely high radiation and electrically noisy environment led us to pick multi-mode fiber optical strain sensors over other types of strain sensors. Special care was taken to minimize the impact of the sensors on the target lifetime. We also placed accelerometers outside the target to try correlating the outside measurements with the internal measurements. Remote manipulators performed the final part of the installation as even residual radiation is too high for humans to come close the targetŠs final location. The initial set of optical sensors on the first instrumented target lasted just long to give us measurements from different proton beam intensities. A second set of more rad-hard sensors, installed in the following target, lasted much longer to give us considerable more data. We are also developing our own rad-hard single-mode fiber optic sensors. This paper describes the design, installation, data-acquisition system, the results of the strain sensors and future plans.

THAM3Y01 **R&D on micro-Loss Monitors for High Intensity Linacs like LIPAc**

Jacques Marroncle (CEA/DSM/IRFU,), Michal Pomorski (CEA/DRT/LIST, Gif-sur-Yvette Cedex), Philippe Abbon, Anthony Marchix (CEA/IRFU, Gif-sur-Yvette)

Before approaching the micro-loss monitor concept, we propose to present the high intensity Linac for which the R&D program was done, LIPAc (Linear IFIMIF Prototype Accelerator). This later is the feasibility accelerator demonstrator for the International Fusion Materials Irradiation Facility (IFMIF). IFMIF aims at providing a very intense neutron source (10**18 neutron/m2/s) to test materials for the future fusion reactors, beyond ITER (International Thermonuclear Experimental Reactor). LIPAc (1.125 MW deuteron beam) is in installation progress at Rokkasho (Japan). Then, we will focus on the feasibility study of the beam optimization inside the SRF Linac part. Commissioning of such high beam intensity has to be done with a different approach based on detection of micro-losses, CVD diamonds, set inside the cryomodule linac.

THAM4Y01 **New Arrangement of Collimators of J-PARC Main Ring**

Masashi Shirakata, Susumu Igarashi, Koji Ishii, Yoichi Sato, Junpei Takano (KEK, Ibaraki)

The beam collimation system of J-PARC main ring has been prepared in order to localize the beam loss into the specified area, especially during the injection period. At the first time, it was constructed as a scraper-catcher system in horizontal and vertical planes which consisted of one halo-scraper and two scattered protons catchers, whose the maximum beam loss capacity was designed to be 450W in the beam injection straight of the ring. In 2012, the scraper was replaced by two collimators with a movable L-type jaw for both planes. Two catchers remained at the same places, and they were used as collimators. This large change of design concept of main ring collimation system was required in order to increase the beam loss capacity more than 3kW. The system worked well but unexpected loss spots still remained in the following arc and straight sections. The four-axis collimator was developed with movable jaw in horizontal, vertical and skew configurations which has high cleaning efficiency. We have four four-axis collimators, two non-skew collimators, and one original catcher. The most effective arrangement of collimators was investigated in this report.

THAM5Y01 **Path to Beam Loss Reduction in the SNS Linac Using Measurements, Simulation and Collimation**

Alexander V. Aleksandrov (ORNL, Oak Ridge, Tennessee)

The SNS linac operation at its design average power currently is not limited by uncontrolled beam loss. However, further reduction of the beam loss remains an important aspect of the SNS linac tune up and operation. Even small ŞacceptableŤ beam loss leads to long term degradation of the accelerator equipment. The current state of model-based tuning at SNS leaves an unacceptably large residual beam loss level and has to be followed by an empirical, sometimes random, adjustment of many parameters to reduce the loss. This talk will discuss a set of coordinated efforts to develop tools for large dynamic range measurements, simulation and collimation in order to facilitate low loss linac tuning.

THAM6Y01 **Simulations and Detector Technologies for the Beam Loss Monitoring System at the ESS Linac**

Irena Dolenc Kittelmann, Thomas Shea (ESS, Lund)

The European Spallation Source (ESS), which is currently under construction, will be a neutron source based on 5 MW, 2 GeV superconducting proton linac. Among other beam instrumentation systems, this high intensity linac requires a Beam Loss Monitoring (BLM) system. An important function of the BLM system is to protect the linac from beam-induced damage by detecting unacceptably high beam loss and promptly inhibiting beam production. In addition to protection functionality, the system is expected to provide the means to monitor the beam losses during all modes of operation with the aim to avoid excessive machine activation. This paper focuses on the plans and recent results of the beam loss studies based on Monte Carlo simulations in order to refine the ESS BLM detector requirements by providing the estimations on expected particle fluxes and their spectra at detector locations. Furthermore, the planned detector technologies for the ESS BLM system will be presented.

THAM7Y01 **Beam-Material Issues for Instrumentation in a 5 MW Monolith**

Monika Hartl, Yongjoong Lee, Thomas Shea, Cyrille Thomas (ESS, Lund)

With the European Spallation Source (ESS) striving to become the worldŠs most powerful spallation neutron source, the proton accelerator driving the spallation process at ESS has to be very powerful as well. The 5MW/2GeV proton beam delivered from a superconducting linear accelerator sets quite demanding requirements on the beam diagnostic system located in the proton beam instrumentation plug (PBIP). This system is observing beam properties and contains multi-wired grids for beam profile monitoring, thermocouples and secondary emission blades for aperture monitoring and a luminescent coating for imaging the beam spot on the target. These devices are critical for detection of any missteering of the beam and consequently for machine protection. Since the components are exposed to high doses of radiation, radiation damage is to be expected and it is challenging to ensure full functionality of the diagnostic system over a set period of runtime. Material choices for these components in the PBIP with respect to lifetime in a radiation field and operational criteria will be presented.

THAM8Y01 **Developments in Non-destructive Beam Profile Monitors**

Carsten Peter Welsch (Cockcroft Institute, Warrington, Cheshire; The University of Liverpool, Liverpool)

Non-interceptive beam profile monitors are of great importance for many particle accelerators worldwide. Extra challenges are posed by high energy, high intensity machines and low energy low intensity accelerators. For these applications, existing diagnostics will not be suitable any more due to the high power of the beam or the very small intensities. In addition, many other accelerators ranging from medical to industrial would benefit from the availability of truly non-invasive and real-time beam profile monitors. This contribution presents the different beam monitoring options used at facilities around the world. After a general overview and a discussion of the figures of merit, it focuses on the design details and experimental results of a gas jet-based beam profile monitor at the Cockcroft Institute. It will be shown that this can be operated either as a supersonic gas jet in high vacuum or a residual gas monitor at higher pressures, basing imaging on either atom ionization or light emission.

THPM1Y01 **The Optimization Design of CIADS Linac**

Shuhui Liu, Weilong Chen, Yuan He, Huan Jia, Yue Tao, Zhijun Wang (IMP/CAS, Lanzhou)

Chinese government has approved the CIADS project, which aims to demonstrate the nuclear waste transmutation technology. The CIADS driver accelerator is designed to be a 250MeV, 10mA CW operation superconducting linac. The main issue of such high power large-scale facility is the construction cost and beam loss control. For superconducting linac, the main cost is spent on the superconducting cavity and RF amplifier system. The improvement of acceleration efficiency of cavity and utilization of RF amplifiers will be useful for the cost saving. The other beam physics issues including lattice design, error simulation and adapted compensation strategy are also studied. In the talk, the cost optimization as well as beam physics considerations will be presented.

THPM2Y01 **Instability of CW RFQ With High Beam Loading**

Ran Huang, Yuan He, Hongwei Zhao (IMP/CAS, Lanzhou)

The frequency detuning as large as 10 kHz observed on the RFQ of the Injector II of the CIADS when the beam passed by couldnŠt be explained by the beam loading theory based on the equivalent circuit analysis, which is a mainstream theory being widely used in the analysis of beam loading nowadays. By introducing the concept of beam-cavity system, together with the impedance model of the beam, the beam induced detuning of the beam-cavity system was proved to be amount to the optimum detuning of the cavity under the given beam condition in a very straightforward way and the problem was therefore converted to the calculation of the optimum detuning of the RFQ. With the introduction of the new notions of effective synchronous phase and RF phase, the existing beam loading theory is extended to the analysis of the more complex accelerating structures, such as RFQ, which has many accelerating cells and with different synchronous phase in each cell, along with more than one dominant mode coexisting in the cavity. The numerical result obtained from the extended beam loading theory was well agreed with the experiment result mentioned at the beginning.

THPM3Y01 **Space Charge Resonances in Linacs**

Ciprian Plostinar (STFC/RAL/ASTeC, Chilton, Didcot, Oxon)

Space charge driven resonances in proton linacs have long been recognised as possible sources of emittance growth and halo development, with potentially severe consequences for beam quality and transmission rates. With increasing demand for high intensity, high power beams, understanding and quantifying these effects has become an essential step in any accelerator design. In this paper we briefly review the current resonance models, we analyse the design approach taken in several modern machines and we highlight the latest experimental efforts undertaken to validate theoretical models and code predictions.

THPM5Y01 **Beam dynamics studies for a multi-ion linac injector to EIC booster**

Peter Ostroumov, Zachary Alan Conway, Brahim Mustapha (ANL, Argonne), Alexander Plastun (ANL, Argonne, Illinois)

The electron-ion collider being developed at JLAB requires a new ion accelerator complex which includes a linac capable of delivering any ion beam from hydrogen to lead to the booster. We are currently developing a linac which consists of several ion sources, a normal conducting (NC) front end, up to 5 MeV/u, and a SC section for energies > 5 MeV/u. The development work is focused on beam dynamics and electrodynamics studies to design efficient and cost-effective accelerating structures for both the NC and SC sections of the linac. Currently we are considering two RFQs following either heavy-ion sources or light-ion sources including polarized beams, and several different types of NC accelerating structures downstream of the RFQ. Quarter-wave and half-wave resonators can be effectively used in the SC section.

THPM6Y01 **Collective Beam Instability and Beam Halo Due to Space Charge**

Chao Li, Zhicong Liu, Qing Qin (IHEP, Beijing), Robert Jameson (IAP, Frankfurt am Main)

The collective mode instability in high intensity ion beam induced by space charge has been studied for several decades. Beam halo also will be formed if beam is located in the collective mode unstable stop band. In this paper, firstly we clearly show that the beam surface is distorted by the space charge potential perturbation; the formed n-fold structure is in particular to the nth order unstable collective mode. Secondly, the formed n-fold structure will lead to beam halo with beam evolution. The halo mechanism could be depicted by resonance between single particle and oscillation collective mode. Finally, we proved that the halo particles are those whose actions were modified significantly by the nonlinear space charge and resonance.

THPM7Y01 **A New RFQ Model and Symplectic Multi-Particle Tracking In the IMPACT Code**

Ji Qiang (LBNL, Berkeley, California)

The IMPACT code is a self-consistent parallel three-dimensional beam dynamics simulation code that combines the magnetic optics method and the parallel particle-in-cell method. It has been widely used to study high intensity/high brightness beams in many accelerators. In this paper, we will report on recent improvements to the code such as a capability to model RFQ and symplectic multi-particle tracking using a spectral method.

THPM8Y01 **Space Charge Neutralized H- Beam Transport at Low Energies**

Deepak Raparia (BNL, Upton, Long Island, New York)

At Brookhaven for H- linac we are using Magnetron source which provides more than 100 mA of H- .This high current beam transport to RFQ over two meters is a challenge with Magnetic LEBT, we use noble gases to charged neutralized the beam and have success fully gain 10-20% integrated beam out of linac

THPM9Y01 **An Advanced Procedure for Longitudinal Beam Matching for the SC CW Heavy Ion Linac With Variable Output Energy**

Stepan Yaramyshev (GSI, Darmstadt; MEPhI, Moscow), Viktor Gettmann, Sascha Mickat, Maksym Miski-Oglu (GSI, Darmstadt; HIM, Mainz), Winfried A. Barth (GSI, Darmstadt; HIM, Mainz; MEPhI, Moscow), Manuel Heilmann (GSI, Darmstadt; IAP, Frankfurt am Main), Kurt Aulenbacher (HIM, Mainz; IKP, Mainz)

A multi-stage programm for the developmnet of a heavy ion superconducting (SC) continuous wave (CW) linac is in progress at HIM (Mainz, Germany), GSI (Darmstadt, Germany) and IAP (Frankfurt, Germany). The main beam acceleration is provided by up to nine multi-gap CH cavities. Due to variable beam energy, which coud be provided by each cavity separate, a longitudinal beam matching to each cavity is extremely important. The linac should provide the beam for physics experiments, smothly varying the output particle energy from 3.5 to 7.3 MeV/u, simultaneously keeping high beam quality. A dedicated algorythm for such a complicate matching, providing for the optimum machine settings (voltage and rf phase for each cavity), has been developed. The description of method and the obtained reasuts are discussed in this paper.

7.8 Friday

Plenary Session, Friday, 2016 July 8, 9:00-12:40

FRAM2P01 **Summary WG-A**

Friday Summary

FRAM3P01 **Summary WG-B**

Friday Summary

FRAM4P01 **Summary WG-C**

Luc Perrot (IPN, Orsay)

Friday Summary

FRAM5P01 **Summary WG-D**

Friday Summary

FRAM6P01 **Summary WG-E**

Friday Summary

FRAM7P01 **Plasma Accelerators**

Robert Bingham (STFC/RAL/ASTeC, Chilton, Didcot, Oxon)

Particle accelerators developed last century are approaching the energy frontier. Today at the terascale the machines needed are extremely large and costly, even the smaller scale lower energy accelerators are not small. For a number of years plasma based particle accelerators driven by either lasers or particle beams are showing great promise as future replacements, primarily due to the extremely large accelerating electric fields they can support, about a thousand times greater than conventional accelerators leading to the possibility of compact structures. But will they be a serious competitor and displace the conventional Şdinosaurŧ variety? The impressive results that have so far been achieved show considerable promise for future plasma accelerators at the energy frontier as well as providing much smaller Ştable-topŧ ion and electron accelerators. A number of schemes are now being investigated for both high energy lepton and hadron beams. In this talk I will give an overview of the current laser plasma acceleration techniques, in particular the possibility of plasma acceleration of high intensity hadron beams in the future.

6 List of Participants

The affiliations are extracted from the JACoW profiles.
Peter AAKERSTEN, ***Scandinova Systems AB***
Dean ADAMS, ***STFC/RAL/ASTeC***
Philip ADAMSON, ***Fermilab***
Alexander ALEKSANDROV, ***ORNL***
Emilio ASENSI, ***ESS ERIC***
Helen BARMINOVA, ***MEPhI***
Winfried BARTH, ***MEPhI***
Hannes BARTOSIK, ***CERN***
Luca BELLAN, ***Univ. degli Studi di Padova***
Elena BENEDETTO, ***CERN***
Dan BERKOVITS, ***Soreq NRC***
Chandra BHAT, ***Fermilab***
Pushpalatha BHAT, ***Fermilab***
Robert BINGHAM, ***STFC/RAL/ASTeC***
Willem BLOKLAND, ***ORNL***
Oliver BOINE-FRANKENHEIM, ***TEMF, TU Darmstadt***
Elian BOUQUEREL, ***IPHC***
Chiara BRACCO, ***CERN***
Roderik BRUCE, ***CERN***

Alexey BUROV, ***Fermilab***
Rama CALAGA, ***CERN***
Jianshe CAO, ***IHEP***
Manuel CARGNELUTTI, ***I-Tech***
Weiping CHAI, ***IMP/CAS***
Nicolas CHAUVIN, ***CEA/IRFU***
Vera CHETVERTKOVA, ***GSI***
Benjamin CHEYMOL, ***ESS ERIC***
Yunlong CHI, ***IHEP***
Alexander CHIKHACHEV, ***Private Address***
Yong Ho CHIN, ***KEK***
Yong-Sub CHO, ***KAERI***
Claude VAN DAELE, ***CPI***
Michele COMUNIAN, ***INFN/LNL***
Nathan COOK, ***RadiaSoft LLC***
Thales CORREA DA SILVA, ***IF-UFRGS***
Sarah COUSINEAU, ***ORNL***
Håkan DANARED, ***ESS ERIC***
Krister DANIELSSON, ***Beckhoff Automation GmbH***
Renato DE PRISCO, ***ESS ERIC***
Bernd DEHNING, ***CERN***
Veliko DIMOV, ***CERN***

George DODSON, ***ORNL***
Irena DOLENC KITTELMANN, ***ESS ERIC***
Patxi DUTHIL, ***IPN***
Oscar ELMQVIST SANDVIK, ***ESS ERIC***
Anton ELSASSER, ***FuG Elektronik GmbH***
Mohammad ESHRAQI, ***ESS ERIC***
Nicholas EVANS, ***ORNL RAD***
Wolfram FISCHER, ***BNL***
Giuliano FRANCHETTI, ***GSI***
Shinian FU, ***IHEP***
Fernanda GARCIA, ***Fermilab***
Roland GAROBY, ***ESS ERIC***
Simone GILARDONI, ***CERN***
Timofey GORLOV, ***ORNL***
Denéle GOUS, ***ESS ERIC***
Slava GRISHIN, ***ESS ERIC***
Xiaofeng GU, ***BNL***
Malek HAJ TAHAR, ***BNL***
Carsten HANSEN, ***Danfysik A/S***
Monika HARTL, ***ESS ERIC***
Yuan HE, ***IMP/CAS***
Ingo HOFMANN, ***GSI***

Hideaki HOTCHI, ***JAEA/J-PARC***
Ran HUANG, ***IMP/CAS***
Alexander HUSCHAUER, ***CERN***
Susumu IGARASHI, ***KEK***
Masanori IKEGAMI, ***FRIB***
Zunbeltz IZAOLA, ***ESS Bilbao***
Si-Won JANG, ***Korea University Sejong Campus***
Ji-Ho JANG, ***IBS***
Dong-O JEON, ***IBS***
Hongfei JI, ***IHEP***
Huan JIA, ***IMP/CAS***
Hyunchang JIN, ***IBS***
Mikael JOHANSSON, ***ESS ERIC***
Thomas KALTENBACHER, ***CERN***
Shinichi KATO, ***JAEA/J-PARC***
Frederik KESTING, ***IAP***
Jong-Won KIM, ***IBS***
Peter KOLDA, ***CPI***
Vladimir KORNILOV, ***GSI***
Emanuele LAFACE, ***ESS ERIC***
Jean-Michel LAGNIEL, ***GANIL***
Mike LAMONT, ***CERN***

Valeri LEBEDEV, ***Fermilab***
Hee-Seock LEE, ***PAL***
Jeong Han LEE, ***Private Address***
Yngve LEVINSEN, ***ESS ERIC***
Chao LI, ***IHEP***
Rui LI, ***JLab***
Peng LI, ***IMP/CAS***
Jie LI, ***IMP/CAS***
Kevin LI, ***CERN***
Zhicong LIU, ***IHEP***
Shuhui LIU, ***IMP/CAS***
Yong LIU, ***KEK/JAEA***
Zhengzheng LIU, ***FRIB***
Alessandra LOMBARDI, ***CERN***
Steven LUND, ***LBNL***
Shinji MACHIDA, ***STFC/RAL/ASTeC***
Edgar MAHNER, ***CERN***
Jacques MARRONCLE, ***CEA/IRFU***
Felix MARTI, ***FRIB***
Michaela MARX, ***DESY***
Shin-ichiro MEIGO, ***JAEA/J-PARC***
Lotta METHER, ***CERN***

Elias MÉTRAL, ***CERN***
Mikael LIND, ***Scandinova Systems AB***
Michiko MINTY, ***BNL***
Shekhar MISHRA, ***Fermilab***
Ryoichi MIYAMOTO, ***ESS ERIC***
Zhencheng MU, ***CSNS***
Raphael MUELLER, ***GSI***
Marc MUNOZ, ***ESS ERIC***
Sergei NAGAITSEV, ***Fermilab***
Heiko NIEBUHR, ***IAP***
Daniel NOLL, ***IAP***
Adrian OEFTIGER, ***EPFL***
Johan OLANDER, ***ESS ERIC***
Anna OLSSON, ***Scanditronix Magnet AB***
Maja OLVEGAARD, ***Uppsala University***
Peter OSTROUMOV, ***ANL***
Angelina PARFENOVA, ***PSI***
Alexander PEDERSEN, ***Lund Institute of Technology (LTH)***
ShiXiang PENG, ***PKU***
Jun PENG, ***CSNS***
Luc PERROT, ***IPN***
Tatiana PIELONI, ***CERN***

Ben PINE, ***JAI***
Ciprian PLOSTINAR, ***JAI***
Michael PLUM, ***ORNL***
Aurélien PONTON, ***ESS ERIC***
Robert POTTS, ***ORNL RAD***
Juliana PRANKE, ***ESS ERIC***
Miguel PRETELLI, ***OCEM***
Christopher PRIOR, ***STFC/RAL/ASTeC***
Abril QARAEEN, ***ESS ERIC***
Ji QIANG, ***LBNL***
Danilo QUARTULLO, ***CERN***
Uli RAICH, ***CERN***
Deepak RAPARIA, ***BNL***
Stefano REDAELLI, ***CERN***
Toon ROGGEN, ***CERN***
Charlotte ROOSE, ***ESS ERIC***
Anna RUBIN, ***GSI***
Kiersten RUISARD, ***UMD***
Giovanni RUMOLO, ***CERN***
Tang RUO, ***TUB***
Lawrence RYBARCYK, ***LANL***
Pranab SAHA, ***JAEA/J-PARC***

Volker RW SCHAA, ***GSI***
Michael SCHENK, ***EPFL***
Felix SCHLANDER, ***ESS ERIC***
Frank SCHMIDT, ***CERN***
Elena SHAPOSHNIKOVA, ***CERN***
Thomas SHEA, ***ESS ERIC***
Suzanne SHEEHY, ***STFC/RAL/ASTeC***
Masashi SHIRAKATA, ***KEK***
Andrei SHISHLO, ***ORNL***
Yoshihiro SHOBUDA, ***JAEA/J-PARC***
Giulio STANCARI, ***Fermilab***
William STEM, ***TEMF, TU Darmstadt***
Robin STEWART, ***CPI***
Ivan STRASIK, ***GSI***
Yanfeng SUI, ***IHEP***
Eugene TANKE, ***ESS ERIC***
Inga TEJEDOR, ***ESS ERIC***
Heine THOMSEN, ***Aarhus University***
Rudolf TIEDE, ***IAP***
Malte TITZE, ***CERN***
Garry TRAHERN, ***ESS ERIC***
Nicholaos TSOUPAS, ***BNL***

Francesco VELOTTI, ***EPFL***
Xilong WANG, ***ESS ERIC***
Christopher WARSOP, ***STFC/RAL/ISIS***
Stephen WEBB, ***RadiaSoft LLC***
Herbert WEISS, ***FuG Elektronik GmbH***
Carsten WELSCH, ***The University of Liverpool***
Wu-Tsung WENG, ***BNL***
Per WESTPHAL, ***Exir Broadcasting AB***
Magnus WIBERG, ***Exir Broadcasting AB***
Robert WILLIAMSON, ***STFC/RAL/ISIS***
Walter WITTMER, ***ESS ERIC***
Meiqin XIAO, ***Fermilab***
Qingzi XING, ***TUB***
Masanobu YAMAMOTO, ***JAEA/J-PARC***
Fang YAN, ***IHEP***
Yao YANG, ***Private Address***
Jiancheng YANG, ***IMP/CAS***
Hongjuan YAO, ***TUB***
Stepan YARAMYSHEV, ***MEPhI***
Youjin YUAN, ***Private Address***
Rihua ZENG, ***ESS ERIC***
Ailin ZHANG, ***PKU***

Hongwei ZHAO, ***IMP/CAS***
Jianbing ZHAO, ***IHEP***
Qiang ZHAO, ***FRIB***
Shu-xin ZHENG, ***TUB***
Feng ZHU, ***PKU***
Frank ZIMMERMANN, ***CERN***