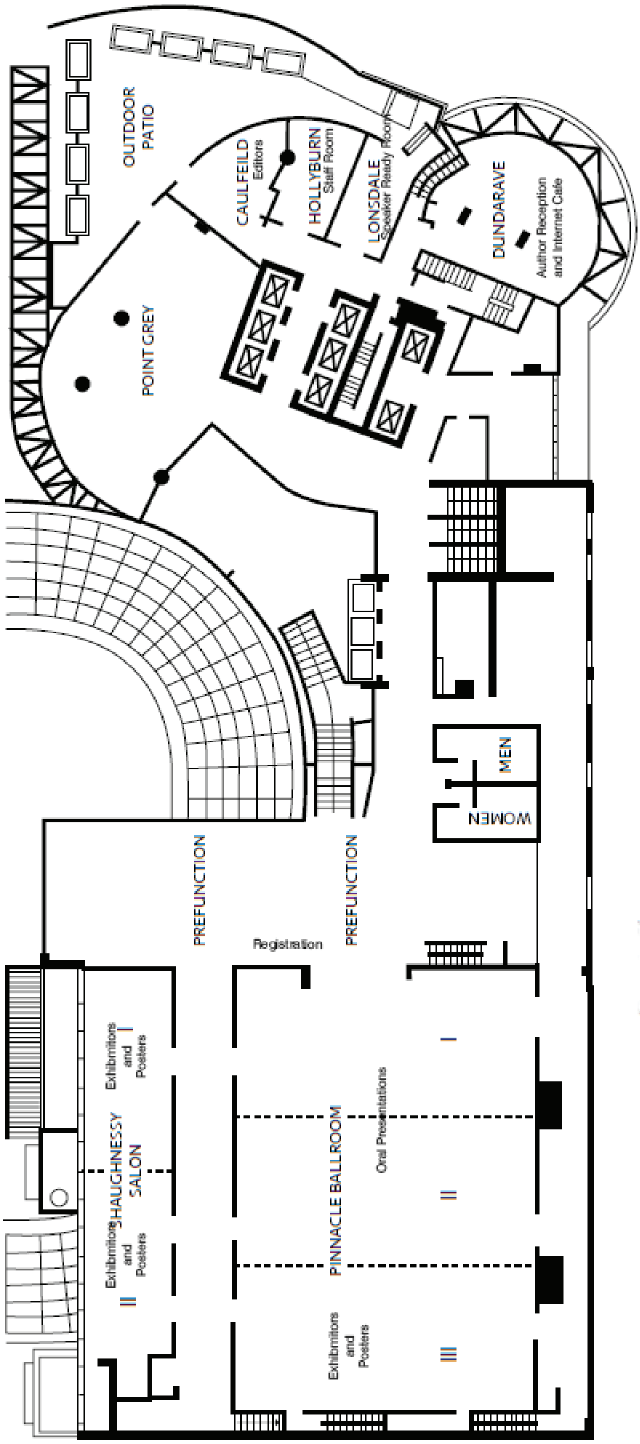
CYCLOTRONS 2013

20TH INTERNATIONAL CONFERENCE ON CYCLOTRONS AND THEIR APPLICATIONS

SEPTEMBER 16 - 20, 2013
Vancouver, BC Canada

CONFERENCE GUIDE

cyc13.triumf.ca



Marriott Pinnacle Downtown
3rd Floor

2013
20th International Conference on Cyclotrons and Their Applications

September 16-20, 2013

Vancouver, British Columbia, Canada

www.triumf.ca/cyc13

The CYC13 conference is held at the:

Vancouver Marriott Pinnacle Downtown Hotel

Organized by
TRIUMF

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Welcome!

Yuri Bylinski
Chairman, CYCLOTRONS'13

The 20th International Conference on Cyclotrons and their Applications (CYCLOTRONS'13) is taking place in Canada's West Coast City of Vancouver, British Columbia from September 16th to 20th 2013. This well-established conference series attracts scientists, engineers, managers and entrepreneurs and students from world-class science laboratories and cyclotron based industrial and medical facilities to discuss scientific, technological, and user aspects of cyclotrons and their applications.

The Scientific Program of the conference is composed of invited and contributed talks and poster sessions. CYCLOTRONS'13 is committed to reaching out to young researchers in the field, and has set a budget to partially support all qualifying students. Also, they will be given an unprecedented opportunity to present their work at the conference.

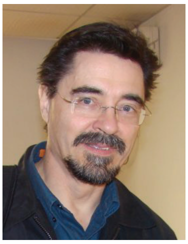
The conference is organized and hosted by TRIUMF, Canada's National Laboratory for Particle and Nuclear Physics. Key CYCLOTRONS'13 organizers include: Yuri Bylinski (Conference Chair), Richard Baartman (Scientific Program Chair), Jozef Orzechowski (Local Organizing Committee Chair), and Jana Thomson (Conference Facilitator and Editor)

On behalf of the Local Organizing Committee, it gives us great pleasure to welcome you to CYCLOTRONS'13, to Vancouver, to British Columbia and to Canada. The Scientific Program Committee has worked diligently on assembling an exciting and stimulating scientific program. Your response to the call for abstracts and your attendance here, during a difficult era in the global economy, affirms our goal to be relevant to the community.

The venue of the conference is the Marriott Pinnacle Downtown Hotel in Vancouver, a beautiful, dynamic city set in a spectacular natural environment. It is one of the few places in the world where you can ski in the morning and golf in the afternoon. Mid September in Vancouver is particularly beautiful, as the sun is still giving a sense of mild summer, ocean waters are just starting to cool down, but the mountain slopes are already changing colors to the Fall palette. Vancouver offers visitors both outstanding opportunities for outdoor adventure and the sophisticated amenities of a world-class city. The 2010 Winter Olympics have helped the city to substantially upgrade its transport infrastructure as well as tourist attractions.

We encourage you to take time to enjoy the history, west coast food and culture of Vancouver. Thank you for participating in CYCLOTRONS'13.

Program Overview



Rick Baartman
Scientific Program Committee Chair

It is interesting to look back to 1959, to the first conference in this series of which the present conference is the twentieth. At that time, and up until 1969, the conference was named "International Conference on Sector-Focused Cyclotrons". This name had been chosen to differentiate this type of accelerator from the previous generation of accelerators, which were weak-focusing with no azimuthal field variation.

Now that more than half of a century has passed, the field of cyclotron design can be considered to have reached a certain level of maturity. Where in the past, the main focus of the conference was to disseminate, discuss, and optimize methods of reaching sufficiently high particle energy and intensity, there is now also a pressing need to pass the learned techniques on to younger people.

For this reason, the Program Committee is emphasizing work done by students and post-docs. Firstly, our invitations for talks and choices of contributed for orals has had somewhat of a bias towards younger people. Rather than having a dedicated student session, these talks and posters are distributed among the regular program.

Secondly, there is a new session besides the regular ones on beam dynamics, facility status, and various applications and technical specialties. The new category could be given the longish name: Small cyclotrons for demonstration, training and education. These are cyclotrons that are built on a small budget for use by students, both for demonstrating known accelerator physics and for cyclotron physics research, but not necessarily to use the resulting high energy beam for other physics. In some cases, those cyclotrons are actually built by students.

In total among the 8 main classifications, there are 172 presentations, of which 23 are invited and 36 others are contributed orals. The remainder are posters. These numbers are in line with previous conferences, but the total is slightly higher than any conference since 1998. As is usual, there are no parallel sessions, so everyone can attend every talk.

There are at most 48 posters in the daily poster time slot, which is 90 minutes in duration. The invited talks are 25 minutes, and the contributed orals are 15 minutes; each talk is followed by a 5 minute discussion period. We welcome your participation.

TRIUMF - Who We Are

TRIUMF was founded in 1968 by Simon Fraser University, the University of British Columbia (UBC), and the University of Victoria to meet research needs that no single university could provide. The University of Alberta joined the TRIUMF consortium almost immediately. There are currently eleven full member and seven associate member universities from across Canada in the consortium that governs TRIUMF.

Since its inception as a local university facility, TRIUMF has evolved into an international laboratory while still maintaining strong ties to the research programs of the Canadian universities. The science program has expanded from nuclear physics to include particle physics, molecular and materials science, and nuclear medicine. TRIUMF provides research infrastructure and tools that are too large and complex for a single university to build, operate, or maintain. Since its opening in 1969, the laboratory has received more than $1 billion of federal investment and $40 million from the Province of British Columbia. The provincial contributions fund the buildings, which are owned by UBC and are located on an 11-acre site in the south campus of UBC. There are over 350 scientists, engineers, and staff performing research on the TRIUMF site. It attracts over 500 national and international researchers every year and provides advanced research facilities and opportunities to 150 students and post-doctoral fellows each year.

TRIUMF's mission is:

- To make discoveries that address the most compelling questions in particle physics, nuclear physics, nuclear medicine, and materials science;
- To act as Canada's steward for the advancement of particle accelerators and detection technologies; and
- To transfer knowledge, train highly skilled personnel, and commercialize research for the economic, social, environmental, and health benefit of all Canadians.

Thank you for joining us for this important conference on cyclotrons and their applications in science, medicine, and technology. Particle accelerators drive much of the modern industrial economy and healthcare systems, and I look forward to what new breakthroughs will be presented at this conference.

Tim Meyer
TRIUMF
Strategic Planning and Communications

General inquiries should be directed to:

Conference Facilitator & Proceedings Editor

Jana Thomson
TRIUMF
4004 Wesbrook Mall
Vancouver, B.C. V6T 2A3
Canada

Phone: 1-604-222-7427
Email: cyc13@triumf.ca

Conference Secretariat

Silke Bruckner
TRIUMF
4004 Wesbrook Mall
Vancouver, B.C. V6T 2A3
Canada

Phone: 1-604-222-7420
Fax: 1-604-222-1074

Conference Organization

Local Organizing Committee

Jozef Orzechowski
Local Organizing Committee Chair

Yuri Bylinski
Cyclotrons 2013 Conference Chair

Rick Baartman
Scientific Program Committee Chair

Jana Thomson
Conference Facilitator and Editor

Silke Bruckner
Conference Secretariat

Gabriel Cojocaru
Conference Sponsorship

Dana Giasson
Website Design and Maintenance

Angela Hoiem
TRIUMF Tour coordinator

Yetvart Hosepyan
Student Support

Fred Jones
SPMS IT Support

Lorraine King
Registration and Editorial Assistant

Corrie Kost
Speaker Interface

Dan Louie
Exhibitor Support

Tim Meyer
Strategic Planning and Communications

Gord Roy
AV Support

Roman Ruegg
ex-LOC Chairman

Bhawandeep Sidhu & Bob Chow
IT Support

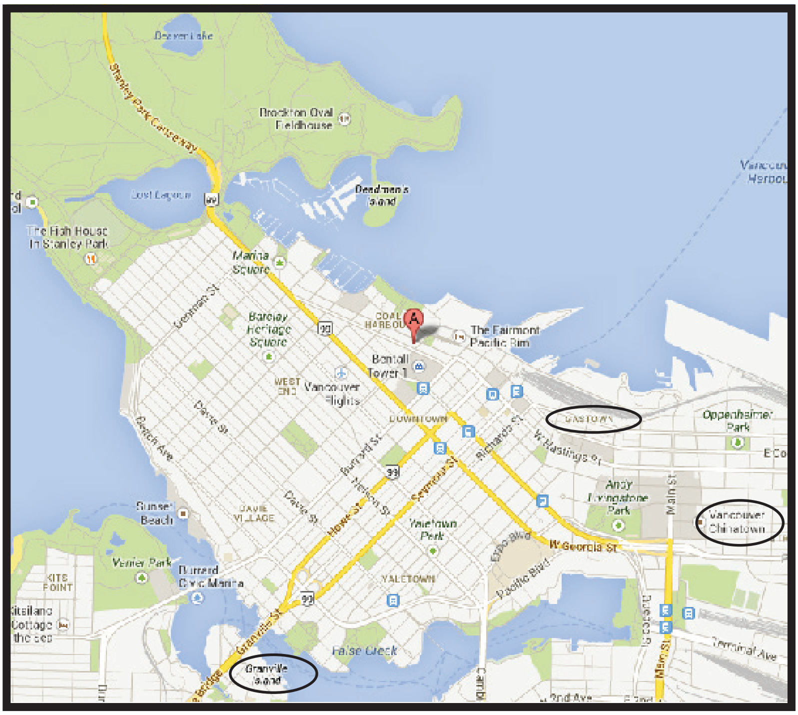
Sean Antonson
PCO Conference Support (Buksa Strategic Conference Services)

International Organizing Committee

Yuri Bylinski, CYCLOTRONS'13 Chair,TRIUMF
P. Bertrand, GANIL
R. Bhandari, VECC
S. Brandenburg, KVI
L. Calabretta, INFN-LNS
J. Conradie, iThemba LABS
M. Craddock, UBC & TRIUMF
A. Denker, Helmholtz-Zentrum Berlin
S. Gales, GANIL
R. Gebel, FZ-Jülich
K. Hatanaka, RCNP
P. Heikkinen, JYFL
Y. Hirao, NIRS
Y. Jongen, IBA
M. Loiselet, UCL
C. Lyneis, LBNL
F. Marti, NSCL/MSU
D. May, TAMU
Y. Mori, KURRI
L. Onischenko, JINR
H. Schweickert, FZK
M. Seidel, PSI
S. Smith, STFC Daresbury
Y. Yano, RIKEN
W. Zhan, IMP
T. Zhang, CIAE

Scientific Program Committee

Rick Baartman, Scientific Program Committee Chair, TRIUMF
Sytze Brandenburg, KVI
Akira Goto, NIRS
Tim Koeth, UMD
Daniela Leitner, NSCL/MSU
Shinji Machida, RAL
Hongwei Zhao, IMP



A Marriott Pinnacle Downtown

Conference Hotel

Vancouver Marriott Pinnacle

Downtown Hotel

1128 West Hastings Street

Vancouver, BC V6E 4R5

Phone: 1-604-684-1128

Fax: 1-604-298-1128

Toll free: 1-800-207-4150

EMERGENCY PHONE NUMBERS AT VENUE:

Vancouver Marriott Pinnacle Downtown Hotel	604-684-1128
(Toll-free)	1-800-207-4150

HOSPITAL:

St. Paul’s Hospital 604-682-2344
1081 Burrard Street
www.providencehealthcare.org

WALK-IN CLINICS:

Ultima Medicentre 604-683-8138
1055 – Plaza Level Bentall 4 Dunsmuir Street
www.ultimamedicentre.ca

Stein Medical Clinic 604-688-5924
Bentall 5 lobby
188 – 550 Burrard Street
www.steinmedical.com

PHARMACIES:

Rexall 604-684-8204
1055 West Georgia St.
www.rexall.ca
(located in the mall attached to the Hyatt Hotel)

Shoppers Drug Mart 604-683-0358
700 W. Georgia Street
www.shoppersdrugmart.com

London Drugs 604-448-4802
710 Granville Street
www.londondrugs.com

Burrard Pharmasave 604-669-7700
101 – 1160 Burrard Street
www.burrardpharmacy.com
(across from St. Paul’s Hospital)

TOURISM

Weather

Vancouver enjoys a temperate climate. During September the mean daily maximum temperature is 18 degrees Celsius and the mean daily minimum is 10 degrees Celsius. You will probably need rainwear at some time.

Travel Information:

Bus and skytrain information:	www.translink.bc.ca
Via Rail:	www.viarail.ca
BC Ferries:	www.bcferries.com
Vancouver International Airport:	www.yvr.ca

BUKSA Strategic Conference Services will be on-site at the Registration Desk to assist with any tourism questions.

COPYING & BANKING

Copying

Staples Business Depot Ltd. 604-678-4873
200-1055 Georgia St.
(same building as the Hyatt Hotel)

Harbour Centre Printing & Copying 604-669-2336
Lower Mall - 555 West Hastings Street

Kinko's Copies 604-685-3338
789 West Pender Street

Banking and Currency Exchange:

RBC Royal Bank
1025 West Georgia Street
Vancouver, BC Tel: 1-800-769-2520

VBCE (Vancouver Bullion & Currency Exchange)
800 West Pender Street, Suite 120
Vancouver, BC V6C 2V6
Hours of Operation:
Monday - Friday
9:00am - 5:00pm Tel: 604-685-1008

REGISTRATION

Hours and Location

The registration desk will be on the 3rd floor of the hotel:

Sunday, September 15	16:00 to 21:00
Monday, September 16	07:30 to 18:00
Tuesday, September 17	07:30 to 18:00
Wednesday, September 18	07:30 to 18:00
Thursday, September 19	08:00 to 13:00
Friday, September 20	08:00 to 13:00

**Times are subject to change.*

What your registration entitles you to:

Full Delegate, Exhibitors & Sponsors, Students, Retiree	• Attendance at all sessions • Reception on Sunday • Banquet on Thursday • Coffee breaks & lunches • Tour of TRIUMF and • Copy of the conference guide • Delegate package
1-day Registration	• Attendance at the sessions for the day chosen • Lunch and coffee breaks for that day only
3-day Registration	• Attendance at the sessions for the days chosen • Reception on Sunday • Banquet on Thursday • Coffee breaks & lunches for days chosen • Tour of TRIUMF • Copy of the conference guide • Delegate package
Companion	• Reception on Sunday • Banquet on Thursday • Lunches • TRIUMF Tour

Participants are asked to wear their conference badges at all Cyclotron 2013-sponsored events.

Extra Tickets, Cancellation, Security

Extra Tickets

Extra tickets for the Banquet are limited. If there are any tickets left, they will be available at Registration. Please request additional tickets before 12:00 noon, Monday, September 16.

Cancellation of Registration

All cancellation requests must be provided in writing to cyc13@triumf.ca. No refunds will be provided for cancellations after July 22, 2013. This policy also applies to extra tickets and companion fees. Refunds may be granted for no-shows under extenuating circumstances. Refunds will be processed after the conference.

Message Board

A message board is located beside the registration desk.

Security and Insurance

CYCLOTRONS'13 and the Vancouver Marriott Pinnacle Downtown Hotel are not responsible for any materials left unattended. The conference organizers cannot accept liability for personal injuries sustained or for loss or damage to participants' (or companions') personal property during the conference.

Luggage Storage:

The hotel will provide luggage storage for their guests.

SOCIAL PROGRAM AND TRIUMF TOUR

Social Events

Sunday, September 15

Welcome Reception 18:00 *Renaissance Hotel*
(across the street from the Marriott Pinnacle Downtown)

TRIUMF Tour and Banquet

Thursday, September 19 *Museum of Anthropology*

A tour of TRIUMF is scheduled for Thursday, September 19. Bus transfer is provided from Vancouver Marriott Pinnacle Downtown Hotel to TRIUMF. The cost for this tour is included with your registration fee.

13:00*	Bus #1 departs Hotel for TRIUMF Tour.
14:00*	Bus #2 departs Hotel for TRIUMF Tour.

16:30*	Bus leaves Hotel for Banquet only.

A bus will be transferring delegates who have gone on the TRIUMF tour from TRIUMF to the banquet location. Delegates will be returned by bus to the hotel following the banquet.

**Times are subject to change.*

CYCLOTRONS'13 COMPANION TOURS

For available excursions, please visit the Landsea Tours and Adventures - CYCLOTRONS'13 website at:
http://vancouvertours.com/cyc2013

Vancouver City and North Shore Tour

Friday, September 20 Afternoon (3 hrs)
$70.00 CAD (including taxes)

The tour begins at the Marriott Pinnacle Downtown Hotel, proceeds by coach through Gastown, Chinatown, Vancouver Harbour and Stanley Park, over the Lions Gate Bridge to the North Shore to Grouse Mountain where there will be a 1.5 hour stop. Guests are returned to the Marriott Pinnacle around 17:00. Please visit the conference website to access the link for registration and payment.
http://cyc13.triumf.ca/excursions.html

Excursions

Please visit: http://vancouvertours.com/cyc2013 for tours offered.

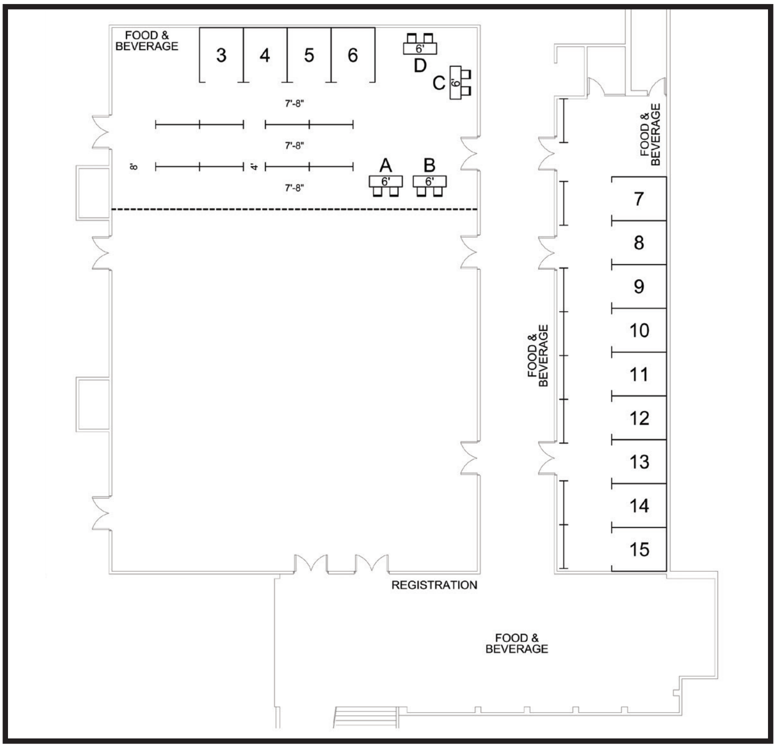
Exhibitor Registration

Exhibitor registration located on the 3rd floor.

Sunday, September 15	16:00 to 21:00
Monday, September 16	07:30 to 12:30

Exhibitors registered at press time.

A. Aerotech Inc.
B. Kurt J. Lesker Company
C. Agilent Technologies
D. Ampegon
3. Phivac Inc.
4. Busch Vacuum
5. MTI (Metal Technology)
6. SIGMAPHI
7. Bext Corporation
8. CCR Process Products
9. Mewasa North America, Inc.,
10. TDK-Lambda High Power
11. Best Cyclotrons Systems Inc.
12. MicroMatter
13. Advanced Cyclotrons
14. Buckley Aerotech Inc.
15. EC^2 Software Solutions



Sponsors

The CYCLOTRONS'13 Organizing Committee, Scientific Program Committee and Local Organizing Committee would like to acknowledge and thank the following for their sponsorship and support:

ACSI - Advance Cyclotrons Systems Inc.
Micromatter
Best Cyclotron Systems Inc.
Dell
D-Pace
Forschungszentrum Jülich – Institute for Nuclear Physics
Nordion
IBA
Busch Vacuum Pumps and Systems
CPI - Communications & Power Industries
Integrated Engineering Software

Student Grants

CYCLOTRONS'13 is supporting 31 students by a variety of ways such as discounting their registration fee, waiving their fee completely, providing accommodation support and travel grants. Travel grants were awarded largely based on recent achievements in the field and merit for the submitted presentation. We are happy to acknowledge the high quality of contributions to the cyclotron field by the following 10 students who are receiving travel grants:

Heidi Baumgartner	MIT	USA
Sean Burcher	Rutgers University	USA
Maximilian Frank	Gynmasium Ernestinum Coburg	Germany
Julia Gonski	Rutgers University	USA
Ellen-Sofie Held	Gynmasium Ernestinum Coburg	Germany
Christoph Kunert	Helmholtz-Zentrum Berlin	Germany
Annalisa Patriarca	University of Roma, La Spienza	Italy
Kiersten Ruisard	University of Maryland	USA
Chuan Wang	China Institute of Atomic Energy	China
Daniel Winklehner	NSCL, MSU	USA

We thank our sponsors for making the funds available to facilitate students' participation at the conference.

WIRELESS INTERNET

Wireless internet is available to all delegates throughout the public areas of the Marrriott Pinnacle Downtown Hotel.

Username:	CYC13
Password:	520mev

An Internet Café is available in the Dundarave Room Located on the 3rd floor of the hotel. A printer is available in the Internet Café.

Sunday	15:00 - 17:30
Monday	08:00 - 18:00
Tuesday	08:00 - 18:00
Wednesday	08:00 - 18:00
Thursday	08:00 - 18:00
Friday	08:00 - 13:00

PROCEEDINGS OFFICE

The Proceedings Office is located in the Dundarave Room. Editorial staff will process papers before and during the conference. The paper submission deadline was Thursday, September 5. Authors are requested to check on their papers via the status board that will be located in or near the Proceedings Office.

Monday	08:00 - 18:00
Tuesday	08:00 - 18:00
Wednesday	08:00 - 18:00
Thursday	08:00 - 18:00
Friday	08:00 - 14:00

**hours at time of printing, subject to change*

ORAL PRESENTATIONS

The Speaker Ready Room is located in the Londsdale Room. Speakers are requested to preview/test their presentations prior to their presentation date/time. Please note that **all** speakers must give their presentations with the computer systems set up in the session room. Use of individual laptops cannot be accommodated.

All talks MUST be uploaded to SPMS at least 24 hours in advance.

POSTER PRESENTATIONS

The poster boards will have a single surface measuring 4’ x 4’ (1.22 m x 1.22 m) so they will accommodate an ARCH E or A0 sized poster in either landscape or portrait orientation.

Day	***Time***	***Location***
Monday	13:30 to 15:00	Pinnacle III Ballroom
Tuesday	13:30 to 15:00	Pinnacle III Ballroom & Shaughnessy
Wednesday	13:30 to 15:00	Pinnacle III Ballroom & Shaughnessy

Posters can be posted on the morning of your scheduled poster time, and must be in place by the beginining of the scheduled session time. They must be staffed by either the presenter or a co-author of the paper. In those cases where presenters have two or more posters in two rooms of the hotel, simultaneously, they are requested to split their time equally between the rooms. Any posters not removed by 19:00 will be removed by staff and discarded.

Authors are reminded that no contributions are accepted for publication only.

Any accepted contributions that are not presented in the oral or poster sessions at the conference will be excluded from the proceedings.

The Scientific Program Committee reserves the right to refuse papers for publication that have not been properly presented or staffed in the poster sessions. Manuscripts of contributions to the proceedings (or enlargements of them) are not considered to be posters, and papers presented in this way will not be accepted for publication.

Identification of Contributions

The date and type of presentation for each contribution in the program can be easily identified from the program code.

Using the example DDTLL###:

- The first two letters indicate the day: MO, TU, WE, TH, FR.
- The third character indicates the time:

  1 (08:30 - 10:30)
  2 (11:00 - 12:00)
  3 (14:00 - 16:00)
  4 (16:30 - 18:00)

- The 4th and 5th letters indicate the room:

  PB (Marriott Pinnacle Ballroom)
  PT (Marriott Pinnacle Ballroom III)
  SH (Marriott Pinnacle Shaughnessy)

The schedule included herein details the scientific program with the program code, title and authors of each paper.

What happens after your paper has been submitted?
The CYCLOTRONS'13 proceedings will be published by the JACoW Joint Accelerator Conferences editorial team. To ensure consistency of the conference proceedings, all papers must meet formal criteria, specified by JACoW.
At the end of the paper submission time, the conference editors start to perform the formal paper checks and conversions according to the JACoW publishing requirements. Once an editor is assigned to your paper he/she produces a PDF file from the uploaded PS file. This PDF file is checked and, if necessary, minor formal corrections are done. The corrected PDF file is uploaded again into your conference database profile. If required, you may be requested to report to the Paper Reception desk to accept the changes made or to speak to an editor if there are concerns with your paper.

To see the "dot board" go to:
http://appora.fnal.gov/pls/cyc13/eDot.html

Green dot:	The paper is ready for publication.
Yellow dot:	Changes or corrections have been made (on the PDF or the original Word/LaTeX source file) and the author is requested to come to Paper Reception to proof-read the modified version.
Red dot:	A major problem occurred. It may be that a file is missing or corrupted and the paper cannot be processed, or there are significant errors with the paper. The author will need to go to Paper Reception immediately to correct the problem.

Scientific Program

Monday, September 16

08:15 Welcome and Announcements

MO1PB Introduction, Facility Development, Commissioning

Session Chairman: Akira Goto

08:40 Acceleration of Intense Heavy Ion Beams in RIBF Cascaded-Cyclotrons [MO1PB01]
Nobuhisa Fukunishi (RIKEN Nishina Center)
09:10 New Developments and Capabilities at the Coupled Cyclotron Facility at MSU [MO1PB02]
Andreas Stolz (Michigan State University)
09:40 Current Status of the Superconducting Cyclotron Project at Kolkata [MO1PB03]
Jayanta Debnath (VECC)

MO2PB Facility Development, Commissioning

Session Chairman: Luciano Calabretta

10:30 What We Learned from EMMA [MO2PB01]
Shinji Machida (Rutherford Appleton Lab)
11:00 High Current Beam Extraction from the 88-Inch Cyclotron at LBNL [MO2PB02]
Damon Todd - (LBL)
11:20 Progress Toward the Facility Upgrade for Accelerated Radioactive Beams at Texas A&M [MO2PB03]
Donald Philip May (Texas A&M)
11:40 Improving the Energy Efficiency, Reliability and Performance of AGOR [MO2PB04]
Mariet Anna Hofstee (KVI, Groningen)

MO3PB Novel Cyclotrons

Session Chairman: Michael Craddock

15:00 An Inverse Cyclotron for Muon Cooling [MO3PB01]
Terrence Lee Hart (Univ. of Mississippi)
15:30 Design Study of a Superconducting AVF Cyclotron for Proton Therapy [MO3PB02]
Hiroshi Tsutsui (Sumitomo Heavy Industries, Ltd.)
15:50 High Gradient Superconducting Cavity Development for FFAG [MO3PB03]
Carol Johnstone (Particle Accelerator Corporation)
16:10 Comparison of Superconducting 230 MeV/u Synchro- and Isochronous Cyclotron Designs [MO3PB04]
Adriano Garonna (CERN)

MO4PB FM Cyclotrons and Scaling FFAGs

Session Chairman: Shinji Machida

17:00 Experimental Study Towards High Beam Power FFAG [MO4PB01]
Tomonori Uesugi (Kyoto University)

17:30 IBA Superconducting Synchrocyclotron Project [MO4PB02]
Willem Kleeven (Ion Beam Applications SA)

18:00 Advanced FFAG Optics, Design and Experiment [MO4PB03]
Jean-Baptiste Lagrange (Kyoto University)

Scientific Program

Tuesday, September 17

TU1PB Ion Sources, Injection
Session Chairman: Pauli Heikkinen

08:30 High Intensity Operation for Heavy Ion Cyclotron of Highly Charged ECR Ion Sources [TU1PB01]
Liangting Sun (Chinese Academy of Sciences)
09:00 ECR Source Development [TU1PB02]
Thomas Thuillier (LBL)
09:30 Ion Dynamics in the Source Using a Detailed PIC-Simulation [TU1PB03]
Vladimir Mironov (KVI, Groningen)
10:00 Recent Development of the RIKEN 28 GHz SC-ECRIS [TU1PB04]
Yoshihide Higurashi (RIKEN)

TU2PB Radio Frequency
Session Chairman: Richard Baartman

10:50 A Study of Multipacting Effects in Large Cyclotron Cavities by Means of Fully 3-Dimensional Simulations [TU2PB01]
Chuan Wang (China Institute of Atomic Energy)
11:20 The New Axial Buncher at INFN-LNS [TU2PB02]
Antonio Caruso (INFN/LNS, Catania)
11:40 Heat Transfer Study and Cooling of 10 MeV Cyclotron Cavity [TU2PB03]
Hossein Afarideh (Amirkabir University of Technology)
12:00 Resonator System for the BEST 70 MeV Cyclotron [TU2PB04]
Vasile Sabaiduc (Best Cyclotron Systems Inc.)

TU3PB Diagnostics, Strippers, Extraction
Session Chairman: Hongwei Zhao

15:00 Bunch-Shape Measurements at PSI’s Highpower Cyclotrons and Proton Beam Lines [TU3PB01]
Rudolf Dölling (PSI)
15:30 Development of a Fiber-Optical Radial Ion Beam Profile and Position Monitor for the 88-Inch Cyclotron at LBNL [TU3PB02]
Markus Michael Strohmeier (LBL)
15:50 R&D of Helium Gas Stripper for Intense Uranium Beams [TU3PB03]
Hiroshi Imao (RIKEN Nishina Center)
16:20 TRIUMF Extraction Foil Developments and Contamination Reduction [TU3PB04]
Yi-Nong Rao (TRIUMF)

TU4PB Magnets

Session Chairman: Yves Jongen

17:10 Mapping of the New IBA Superconducting Synchrocyclotron (S2C2) for Proton Therapy [TU4PB01]
Vincent Nuttens (Ion Beam Applications SA)

17:30 Structural and Magnetic Properties of Pure Iron Cast for Cyclotrons [TU4PB02]
Simon Zaremba (Ion Beam Applications SA)

17:50 Superconducting Beam Transport Channel for a Strong-Focusing Cyclotron [TU4PB03]
Joshua Kellams (Texas A&M University)

18:10 Methods of Increasing Accuracy in Precision Magnetic Field Measurements of Cyclotron Magnets [TU4PB04]
Nikolai Valentinovich Avreline (Advanced Cyclotron Systems Inc)

Scientific Program

Wednesday, September 18

WE1PB Small Cyclotrons for Demo & Education
Session Chairman: Timothy Koeth

08:30 The Houghton College Cyclotron: a Tool for Educating Undergraduates [WE1PB01]
Mark Yuly (Houghton College)
09:00 The Rutgers Cyclotron: Placing Student's Careers on Target [WE1PB02]
Kiersten J. Ruisard (Rutgers University)
09:30 COLUMBUS a Small Cyclotron for School- and Teaching Purposes [WE1PB03]
Christian Rüdiger Wolf (FZJ, Jülich)
09:50 A Novel Optical Method for Measuring Beam Phase and Width in the Rutgers 12-Inch Cyclotron [WE1PB04]
Julia Lynne Gonski (Rutgers University)
10:10 "The Cyclotron Kids" 2 MeV Proton Cyclotron [WE1PB05]
Heidi Baumgartner (MIT)

WE2PB Space Charge
Session Chairman: Sytze Brandenburg

11:00 Review of Space Charge Effects in Cyclotrons [WE2PB01]
Richard Baartman (TRIUMF)
11:30 Vlasov Equation Approach to Space Charge Effects in Isochronous Machines [WE2PB02]
Antoine Cerfon (Courant Inst. of Mathematical Sciences, New York Univ.)
12:00 Transverse-Longitudinal Coupling by Space Charge in Cyclotrons [WE2PB03]
Christian Baumgarten (PSI)

WE3PB Space Charge, Particle Dynamics
Session Chairman: Tianjue Zhang

15:00 Experimental Study of Resonance Crossing with a Paul Trap [WE3PB01]
Hiroshi Sugimoto (KEK, Ibaraki)
15:30 Improvement of the Current Stability in the TRIUMF High-Energy Beam Lines [WE3PB02]
Thomas Planche (TRIUMF)
15:50 Space Charge Compensation Measurements in the Injector Beam Lines of the NSCL Coupled Cyclotron Facility [WE3PB03]
Daniel Winklehner (Michigan State Univ.)

16:10 Transmission of Heavy Ion Beams in the AGOR Cyclotron [WE3PB04]
Ayanangsha Sen (KVI,Groningen)

WE4PB Particle Dynamics, Tracking
Session Chairman:

17:00 Tracking in a Cyclotron with Geant4 [WE4PB01]
Frederick William Jones (TRIUMF)
17:20 An All-Purpose 6-D Tracking Code, Zgoubi [WE4PB02]
Francois Meot (BNL)
17:40 Optimizing the Radioisotope Production with a Weak Focusing Cyclotron [WE4PB03]
Concepcion Oliver (CIEMAT, Madrid)

Scientific Program

Thursday, September 19

TH1PB High Intensity, Applications
Session Chairman: Ralf Gebel

08:30 Operational Experience at the Intensity Limit in Compact Cyclotrons [TH1PB01]
Gabriel Cojocaru (TRIUMF)
09:00 Commissioning of the PSI 590 MeV Ringcyclotron for Accepting and Accelerating a Rebunched 72 MeV Proton Beam [TH1PB02]
Martin Humbel (PSI)
09:20 Activation Analysis with Charged Particles: Theory, Practice and Potential [TH1PB03]
Mohammad Anwar Chaudhri (Inst. of Biomaterials, Erlangen)
09:40 Fabrication of Hydrophobic Surfaces from Hydrophilic BeO by Alpha-Irradiation-Induced Nuclear Transmutation [TH1PB04]
Eun Je Lee (Korea Atomic Energy Research Institute)

TH2PB Medical Applications
Session Chairman: Jacobus Conradie

10:30 Design of Ultra-Light Superconducting Proton Cyclotron for Production of Isotopes for Medical Applications [TH2PB01]
Malay Kanti Dey (VECC)
11:00 Parasitic Isotope Production with Cyclotron Beam Generated Neutrons [TH2PB02]
Francois M. Nortier (LANL)
11:20 The University of Washington Clinical Cyclotron - a Summary of Current Particles and Energies Used in Therapy, Isotope Production, and Clinical Research [TH2PB03]
Eric Fairbanks Dorman (Univ. of Washington)
11:40 A Multi-Leaf Faraday Cup Especially for Proton Therapy of Ocular Tumors [TH2PB04]
Christoph Siegfried Günter Kunert (HZB, Berlin)

Conference Banquet at Museum of Anthropology, UBC

Scientific Program

Friday, September 20

FR1PB Medical, Rare Isotope Facilities, Tribute to Henry Blosser
Session Chairman: Andrea Denker

08:30 Operation Mode of AIC-144 Multipurpose Isochronous Cyclotron for Eye Melanoma Treatment [FR1PB01]
Galina Karamysheva (JINR)
08:50 Secondary Particle Dose and RBE Measurements Using High-Energy Proton Beams [FR1PB02]
Mitra Ghergherehchi (Sungkyunkwan University)
09:10 The Radio Frequency Fragment Separator: A Time-of-Flight Filter for Fast Fragmentation Beams [FR1PB03]
Thomas Baumann (NSCL/MSU)
09:30 GANIL Operation Status and Upgrade of SPIRAL 1 [FR1PB04]
Omar Kamalou (GANIL)
09:50 Tribute to Henry Blosser [FR1PB05]
TBD

FR2PB Rare Isotope Facilities, Medical Isotopes, Summary
Session Chairman: Iouri Bylinskii

10:30 Construction of Rare-RI Ring in RIBF [FR2PB01]
Masanori Wakasugi (RIKEN)
11:00 Cyclotron Production of Tc-99m [FR2PB02]
Ken Buckley (TRIUMF)
11:30 Conference Summary
Mike Seidel (PSI)

12:00 Closing Remarks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MO1PB — Introduction, Facility Development, Commissioning

Chair: A. Goto (NIRS)

MO1PB00 08:15 25

Welcome and Opening Remarks

I.V. Bylinskii *(TRIUMF)*

Welcome and Opening Remarks

MO1PB01 08:40 30

Acceleration of Intense Heavy Ion Beams in RIBF Cascaded-Cyclotrons

N. Fukunishi *(RIKEN Nishina Center)*

The RIBF cascaded-cyclotrons have obtained, as of December 2012, uranium ion beams with an intensity of as high as 15 pnA (1 kW of power). This was achieved owing to deployment of a 28 GHz ECRIS, a new injector linac, a gas stripper and a bending-power upgrade of RIKEN fixed-frequency Ring Cyclotron as well as improvement of transmission efficiencies through cyclotrons and stability, etc.

MO1PB02 09:10 30

New Developments and Capabilities at the Coupled Cyclotron Facility at MSU

A. Stolz *(NSCL)*

A brief overview of the Coupled Cyclotron Facility will be presented with a focus on the newly commissioned stopped beam and reaccelerated radioactive ion beam capabilities. Commissioning results and operations experience of the combined system of Coupled Cyclotron Facility, A1900 fragment separator, gas stopper, EBIT charge-breeder and ReA linac will be presented.

MO1PB03 09:50 20

Current Status of the Superconducting Cyclotron Project at Kolkata

J. Debnath*, M.K. Dey (VECC)*

The commissioning of Kolkata superconducting cyclotron with internal ion beam had been reported in the last cyclotron conference. At that time, there was gradual beam loss due to poor vacuum. After installing a higher capacity liquid helium plant the cryo-panels were made functional leading to a substantial increase in the beam intensity. It was hoped that higher beam intensity would help in extraction of a measurable fraction of the beam, but that did not happen. Detailed investigation of beam behavior with the help of three beam probes, installed temporarily at three sectors, revealed that the beam goes highly off-centered while passing through the resonance zone. A plastic scintillator based phase probe was mounted on the radial probe and beam phase was measured accurately. It was quite clear that large amount of field imperfection was prohibiting the beam to be extracted. So magnetic field measurement has been started again and considerable amount of harmonic and average field errors have been found. In this paper we report the important developments since 2010.

MO2PB — Facility Development, Commissioning

Chair: L. Calabretta (INFN/LNS)

MO2PB01 10:30 30 **What We Learned from EMMA**

S. Machida, *D.J. Kelliher (STFC/RAL/ASTeC)*

Since the demonstration of acceleration in 2011, the study of EMMA aims for more detailed and quantitative understanding of a linear non-scaling FFAG. The talk will summarise the beam study for the last couple of years which includes effects of resonance crossing, a novel idea of COD correction, etc.

MO2PB02 11:00 20 **High Current Beam Extraction from the 88-Inch Cyclotron at LBNL**

D.S. Todd, *J.Y. Benitez, M.K. Covo, K.Y. Franzen, C.M. Lyneis, L. Phair, P. Pipersky, M.M. Strohmeier (LBNL)*

The low energy beam transport system and the inflector of the 88-Inch Cyclotron have been improved to provide more intense heavy-ion beams, especially for experiments requiring 48Ca beams. In addition to a new spiral inflector* and increased injection voltage, the injection line beam transport and beam orbit dynamics in the cyclotron have been analyzed, new diagnostics have been developed, and extensive measurements have been performed to improve the transmission efficiency. By coupling diagnostics, such as emittance scanners in the injection line and a radially-adjustable beam viewing scintillator within the cyclotron, with computer simulation we have been able to identify loss mechanisms. The diagnostics used and their findings will be presented. We will discuss the solutions we have employed to address losses, such as changing our approach to tuning VENUS and running the cyclotron's central trim coil asymmetrically.

*Ken Yoshiki Franzen, et al. "A center region upgrade of the LBNL 88-Inch Cyclotron", these proceedings

MO2PB03 11:20 20

Progress Toward the Facility Upgrade for Accelerated Radioactive Beams at Texas A&M

***D.P. May**, B.T. Roeder, R.E. Tribble (Texas A&M University Cyclotron Institute) F.P. Abegglen, G. Chubaryan, H.L. Clark, G.J. Kim, G. Tabacaru (Texas A&M University, Cyclotron Institute) J.E. Ärje (JYFL)*

The upgrade project at the Cyclotron Institute of Texas A&M University continues to make substantial progress toward the goal of providing radioactive beams accelerated to intermediate energies by the K500 Cyclotron. The K150, which will function as a driver, is now used extensively to deliver both light and heavy ion beams for experiments. The ion-guide cave for the production and charge-breeding of low-energy radioactive beams has been constructed, and the light-ion guide (LIG) has been commissioned with an internal radioactive source. The charge breeding electron-cyclotron-resonance ion source (CB-ECRIS) has been commissioned with a source of stable 1+ ions, while the injection line leading to the K500 has been commissioned with the injection and acceleration of charge-bred beams. Despite the lack of good field maps, both light and heavy ions beams have been developed for the K150. Progress and plans, including those for the heavy-ion guide (HIG), are presented.

MO2PB04 11:40 20

Improving the Energy Efficiency, Reliability and Performance of AGOR

***M.A. Hofstee**, S. Brandenburg, H. Post, R.A. Schellekens, J.E. de Jong (KVI)*

Over the past few years the nature of the experiments performed with AGOR has changed from long experiments, to sequences of short experiments, often using different beams. In addition the total demand for beamtime has gone down. This has required a change in operating procedures and scheduling. In view of the changing demands, we are continuing our efforts to improve the energy efficiency and reliability of the cyclotron, while at the same time trying to improve performance. While some of the solutions might be unique to our facility, many will have broader applicability. Some case studies will be presented and areas for future improvements identified.

MOPPT — Poster Session: Status, Novel & FM Cyclotrons, Applications

Status

MOPPT001 **Status Report of the Cyclotrons C-30, CS30 and RDS-111 at KFSHRC, Saudi Arabia**
F.M. Alrumayan *(King Faisal Specialist Hospital and Research Centre) M. Vora (Affiliation Request Rejected)*

MOPPT002 **Status of the HZB Cyclotron**
A. Denker*, C.S.G. Kunert, C.R. Rethfeldt, J. Röhrich (HZB) D. Cordini, J. Heufelder, R. Stark, A. Weber (Charite)*

MOPPT003 **20 Years of JULIC Operation as COSY's Injector Cyclotron**
R. Gebel*, R. Brings, O. Felden, R. Maier, D. Prasuhn (FZJ)*

MOPPT004 **Status and Further Development of the PSI High Intensity Proton Facility**
J. Grillenberger*, J.M. Humbel, M. Seidel, W. Tron (PSI)*

MOPPT005 **Present Status of the RCNP Cyclotron Facility**
K. Hatanaka*, M. Fukuda, T. Saito, H. Ueda, T. Yorita (RCNP)*

MOPPT007 **Recent Progress at the Jyväskylä Cyclotron Laboratory**
P. M.T. Heikkinen *(JYFL)*

MOPPT008 **Present Status of Cyclotrons (NIRS-930, HM-18) at NIRS**
S. Hojo*, T. Honma, K. Katagiri, M. Nakao, A. Noda, K. Noda, A. Sugiura (NIRS) A.K. Komiyama, T. Okada, Y. Takahashi (AEC)*

MOPPT009 **Current Status and Latest Developments at the Louvain-la-Neuve University Facility**
M. Loiselet *(UCL)*

MOPPT010 **On-Going Operations with the Cyclotron C70 ARRONAX**
F. Poirier *(SUBATECH)*

MOPPT011 **Variety of Beam Production at the INFN LNS Superconducting Cyclotron**
D. Rifuggiato*, L. Calabretta, L. Cosentino, G. Cuttone (INFN/LNS)*

MOPPT012 **Status of Varian's Superconducting Isochronous ProBeam™ Cyclotrons**
H. Röcken*, M. Abdel-Bary, E.M. Akcoeltekin, P. Budz, M. Grewe, F. Klarner, T. Stephani, P. vom Stein (VMS-PT)*

MOPPT013 **Status Report on the Gustav Werner Cyclotron at TSL, Uppsala**
D. van Rooyen *(TSL)*

MOPPT014 **Installation and Commissioning Progress for CYCIAE-100**
T.J. Zhang*, Shizhong. An, T. Ge, F.P. Guan, S.G. Hou, B. Ji, X.L. Jia, Z.G. Li, Y.L. Lu, G.F. Pan, C. Wang, S.M. Wei, J.S. Xing, F. Yang, H.J. Yao, Z.G. Yin, P.F. Zhang, J.Q. Zhong (CIAE)*

MOPPT015 **Plan of a 70 MeV H⁻ Cyclotron System for the ISOL Driver in the Rare Isotope Science Project**
***J.-W. Kim**, S. Hong, J.H. Kim (IBS)*

Novel Cyclotrons and FFAGs

MOPPT016 **A Configurable 1 Mev Test Stand Cyclotron for High Intensity Ion Source Development**
***F.S. Labrecque**, B.F. Milton, W. Stazyk (BCSI) M.M. Maggiore (INFN/LNL)*

MOPPT017 **EMMA Linear FFAG, Numerical Simulation of Experimental Data**
***F. Méot** (BNL) D.J. Kelliher, S. Machida (STFC/RAL/ASTeC) B.J.A. Shepherd (STFC/DL/ASTeC)*

MOPPT018 **End-to-End 6-D Tracking in EMMA Prototype FFAG**
***F. Méot** (BNL) D.J. Kelliher, S. Machida (STFC/RAL/ASTeC) B.J.A. Shepherd (STFC/DL/ASTeC)*

MOPPT019 **A Compact, High-Energy, High-Intensity CW Racetrack FFAG**
***C. Johnstone** (Fermilab)*

MOPPT020 **Study of a Superconducting Compact Cyclotron for Delivering 20 MeV High Current Proton Beams**
***M.M. Maggiore** (INFN/LNL) L. Bromberg, C.E. Miller, J.V. Minervini, A. Radovinsky (MIT/PSFC)*

MOPPT021 **Commissioning of DC-110 Cyclotron Dedicated for Track Membrane Production**
***I.A. Ivanenko**, S.L. Bogomolov, O.N. Borisov, V.A. Buzmakov, S.N. Dmitriev, A.A. Efremov, B. Gikal, G.G. Gulbekyan, I.V. Kalagin, V.I. Kazacha, N.Yu. Kazarinov, M.V. Khabarov, I.V. Kolesov, V.N. Melnikov, V.I. Mironov, N.F. Osipov, S. Pachtchenko, V.A. Sokolov, A. Tikhomirov (JINR)*

MOPPT022 **Design of New Superconducting Ring Cyclotron for the RIBF**
***J. Ohnishi**, M. Nakamura, H. Okuno (RIKEN Nishina Center)*

MOPPT024 **Radial-sector cyclotrons with different hill and valley field profiles**
***M.K. Craddock** (UBC & TRIUMF)*

FM cyclotrons and scaling FFAGs

MOPPT025 **Optimum Serpentine Acceleration in Scaling FFAG**
***S.R. Koscielniak** (TRIUMF)*

Applications

MOPPT026 **ADS Fission in a Molten Salt Core Destroy Transuranics in Spent Nuclear Fuel, Close the Nuclear Fuel Cycle**
***P.M. McIntyre** (Texas A&M University)*

MOPPT027 **Eigenvalues and Surface Impedance of Laminated Circular Waveguide**
***M. Ivanyan**, A. Grigoryan, V.M. Tsakanov (CANDLE)*

MOPPT028 **Charged Particle Wakefield Radiation from the Open End of Semi-Infinite Circular Two-Layer Waveguide**
M. Ivanyan, *A. Grigoryan, V.M. Tsakanov (CANDLE)*

MOPPT029 **The g-2 High-Energy Cyclotron Storage Ring**
C. Johnstone *(Fermilab)*

MOPPT030 **Past, Present and Future Activities for Radiation Effects Testing at JULIC/COSY**
S.K. Hoeffgen, *S. Metzger (FhG) R. Brings, O. Felden, R. Gebel, R. Maier (FZJ) M. Brugger, R. Garcia Alia (CERN)*

MOPPT031 **SPES Project: A Neutron Rich ISOL Facility for Re-Accelerated RIBs**
A. Lombardi, *A. Andrighetto, G. Bisoffi, M. Comunian, P. Favaron, F. Gramegna, L. AC. Piazza, G.P. Prete, D. Zafiropoulos (INFN/LNL)*

MO3PB — Novel Cyclotrons

Chair: M.K. Craddock (UBC & TRIUMF)

MO3PB01 15:00 30

An Inverse Cyclotron for Muon Cooling

T.L. Hart *(UMiss)*

The production of intense high energy muon beams for muon colliders is an active area of interest due to the muon's large mass and pointlike structure. The muon production and the subsequent preparation into a beam are challenging due to the large emittance of the initial beam and the short muon lifetime. Most muon cooling channels being developed are single-pass structures due to the difficulty of injecting large emittance beams into a circular device. Inverse cyclotrons can potentially solve the injection problem using single turn energy loss injection and also reduce the muon beam emittance by a large factor. An end-to-end simulation of an inverse cyclotron for muon cooling is presented performed with G4Beamline, a GEANT-based particle tracking simulation program. Muons are collected in a central trap and then all ejected together.

MO3PB02 15:30 20

Design Study of a Superconducting AVF Cyclotron for Proton Therapy

H. Tsutsui*, A. Hashimoto, Y. Mikami, H. Mitsubori, T. Mitsumoto, Y. Touchi, T. Ueda, K. Uno, K. Watazawa, S. Yajima, J.Y. Yoshida, K.U. Yumoto (SHI)*

Since a cyclotron has better beam quality than that of a synchrocyclotron, we have designed a 4 Tesla superconducting AVF cyclotron for proton therapy. Its weight is less than 60 tons, which is about one fourth of our normal conducting 230 MeV cyclotron. In order to reduce the size and the weight without deteriorating the beam stability, the hill gap around the outer pole radius is made small. Calculated extraction efficiency is higher than 60%, by arranging the extraction elements properly. The low temperature superconducting coil using NbTi wire is conduction-cooled by 4K GM cryocooler. Three dimensional electromagnetic finite element codes have been used during all phases of basic design.

MO3PB03 15:50 20

High Gradient Superconducting Cavity Development for FFAG

C. Johnstone, R.D. Ford, C. Johnstone (PAC) Z.A. Conway, P.N. Ostroumov (ANL)

Like the cyclotron, the Fixed Field Alternating Gradient machine (FFAG) is a compact accelerator with variety of applications in industry and medicine. High intensity, fixed-field compact accelerators require enhanced orbit separation to minimize beam losses especially at extraction. In medium energy and compact FFAGs, this requires a total voltage of ~20 MV per turn with continuous wave accelerating gradients of ~10MV/m, which can only be achieved using superconducting accelerating cavities. This high voltage can be generated using 4 superconducting (SC) cavities operating at higher harmonics of the beam revolution, equal to approximately 200 MHz. The cavities and cryomodule are inserted into a 2m straight section of a racetrack-shaped FFAG. However, as with cyclotrons, the FFAG has a large horizontal acceleration aperture presenting a challenging problem for SCRF cavity design. In this work, we present SC cavity design with 50 cm x 1 cm beam apertures, their electrodynamics optimization, and multiphysics analysis. To achieve a 1 mA average beam current, each cavity is powered by two 100 kW RF couplers.

MO3PB04 16:20 20

Comparison of Superconducting 230 MeV/u Synchro- and Isochronous Cyclotron Designs for Therapy with Cyclinacs

A. Garonna (CERN) U. Amaldi, A. Laisné (TERA) L. Calabretta, D. Campo (INFN/LNS)

This work presents new superconducting compact cyclotron designs for injection in CABOTO, a linac developed by the TERA Foundation delivering C^{6+}/H^{2+} beams up to 400 MeV/u for ion beam therapy. Two designs are compared in an industrial perspective under the same design constraints and methods: a synchrocyclotron and an isochronous cyclotron, both at the highest possible magnetic field and with an output energy of 230 MeV/u. This energy allows us to use the cyclotron as a stand-alone accelerator for proton therapy. The synchrocyclotron design features a central magnetic field of 5 T and an axisymmetric pole and a constant field index. The beam is injected axially with a spiral inflector. Resonant extraction allows beam ejection with moderate beam losses. The RF system operates in first harmonic (180^o Dee), with modulation provided by a large rotating capacitor. The isochronous cyclotron design features a 3.2 T central magnetic field, four sectors and elliptical pole gaps in the hills and in the valleys. Spiraling is minimized and beam ejection is achieved with a single electrostatic deflector placed inside an empty valley. The two RF cavities operate in fourth harmonic.

16-Sep-13 17:00 – 18:30 Pinnacle Ballroom

MO4PB — FM cyclotrons and scaling FFAGs

Chair: S. Machida (STFC/RAL/ASTeC)

MO4PB01 17:00 30

Experimental Study Towards High Beam Power FFAG

T. Uesugi *(Kyoto University, Research Reactor Institute)*

The FFAG complex at KURRI is not only the first proton FFAG accelerator facility for beam users but the one aiming to have high beam power. The talk will present various efforts to increase beam power for the last few years and systematic strategy in near future toward the space charge limit.

MO4PB02 17:30 30

IBA Superconducting Synchrocyclotron Project

W.J.G.M. Kleeven *(IBA)*

In 2009 IBA decided to start the development of a compact superconducting synchrocyclotron as a proton-source for the small footprint proton therapy system called Proteus One ®. The cyclotron has been completely designed and constructed and is currently under commissioning at the IBA factory. Its design and commissioning results will be presented.

MO4PB03 18:00 30

Advanced FFAG Optics, Design and Experiment

J.-B. Lagrange*, Y. Ishi, Y. Kuriyama, Y. Mori, T. Uesugi (Kyoto University, Research Reactor Institute) S.J. Brooks (STFC/RAL/ASTeC)*

Much progress has been made in the FFAG design with novel ideas, for example, FFAG straight line, FFAG with race track shape, FFAG with vertical orbit excursion, etc. Some of these were demonstrated experimentally. The talk will review the recent progress around the world.

TU1PB — Ion Sources, Injection

Chair: P. M.T. Heikkinen (JYFL)

TU1PB01 08:30 30

High Intensity Operation for Heavy Ion Cyclotron of Highly Charged ECR Ion Sources

L.T. Sun *(IMP)*

Modern advanced ECR ion source can provide stable and reliable high charge state ion beams for the routine operation of a cyclotron, which has made it irreplaceable, particularly with regard to the performance and efficiency that a cyclotron complex could achieve with the ion source. The 3rd generation ECR ion sources that can produce higher charge state and more intense ion beams have been developed and put into cyclotron operation since early 21st century. They have provided the privilege for the cyclotron performance improvement that has never been met before, especially in term of the delivered beam intensity and energy, which has greatly promoted the experimental research in nuclear physics. This paper will have a brief review about the development of modern high performance high charge state ECR ion sources. Typical advanced high charge state ECR ion sources with fully superconducting magnet, such as SERSE, VENUS, SECRAL, SuSI and RIKEN SC-ECRIS will be presented, and their high intensity operation status for cyclotrons will be introduced as well.

TU1PB02 09:00 30

ECR Source Development

T. Thuillier *(LBNL)*

Trends in ECR ion source development and perspectives for performance improvement.

TU1PB03 09:30 30

Ion Dynamics in the Source Using a Detailed PIC-Simulation

***V. Mironov**, J.P.M. Beijers, S. Brandenburg (KVI)*

To better understand the physical processes in ECRIS plasmas, we developed a Particle-in-Cell code that follows the ionization and diffusion dynamics of ions. The basic features of the numerical model are given elsewhere*. Electron temperature is a free parameter and we found that its value should be about 1 keV to reproduce the experimentally observed performance of our 14 GHz ECR source. We assume that a pre-sheath is located outside the ECR zone, where the ion acceleration toward the walls occurs. Electric fields inside the ECR zone are assumed to be zero. The ion production is modeled assuming ion confinement by a ponderomotive barrier formed at the boundary of the ECR zone. The barrier height is defined by the RF radiation density at the electron resonance layer and is taken as an adjustable parameter. With these assumptions, we are able to reproduce the main features of ECRIS performance, such as saturation and decrease of highest charge state currents with increasing gas pressure, as well as reaction to an increase of injected RF power. Study of the source response to variations of the source parameters is possible.

*V. Mironov and J. P. M. Beijers, "Three-dimensional simulations of ion dynamics in the plasma of an electron cyclotron resonance ion source", Phys. Rev. ST Accel. Beams 12, 073501 (2009).

TU1PB04 10:00 20

Recent Development of the RIKEN 28 GHz SC-ECRIS

***Y. Higurashi** (RIKEN Nishina Center)*

Since we obtained first beam from RIKEN 28GHz SC-ECRIS in 2009, we tried to increase the beam intensity using various methods. Recently, we observed that the use of Al chamber strongly enhanced the beam intensity of highly charged U ion beam. Using this method, we obtained ~180eμA of U^{35+} and ~230eμA of U^{33+} at the injected RF power of ~3kW with sputtering method. Advantage of this method is that we can insert the large amount of material into the plasma chamber, therefore, we can produce the beam for long term without break. Actually, we already produced intense U beams for the RIBF experiments longer than month without break. For the long term operation, we observed that the consumption rate of the U metal was ~4mg/h. In this spring, we also produced U beam with high temperature oven and two frequencies injection. In these test experiments, we observed that the beam intensity of highly charged U ions is strongly enhanced. In this contribution, we report the various results of the test experiments for production of highly charged U ion beam. We also report the experience of the long term production of the U ion beam for RIKEN RIBF experiments.

TU2PB — Radio Frequency

Chair: R.A. Baartman (TRIUMF)

TU2PB01 10:50 30

A Study of Multipacting Effects in Large Cyclotron Cavities by Means of Fully 3-Dimensional Simulations

C. Wang *(CIAE)*

The field emission model and the secondary emission model, as well as 3D boundary geometry handling capabilities, are needed to efficiently and precisely simulate multipacting phenomena. These models have been implemented in OPAL, a parallel framework for charged particle optics in accelerator structures and beam lines. The models and their implementation are carefully benchmarked against a non-stationary multipacting theory. A dedicated multipacting experiment with nanosecond time resolution for the classic parallel plate geometry has also successfully shown the validity of OPAL model. Multipacting phenomena, in the CYCIAE-100 cyclotron, under construction at China Institute of Atomic Energy, are expected to be more severe during the RF conditioning process than in separate-sector cyclotrons. This is because the magnetic fields in the valley are stronger, which may make the impact electrons easier to reach energies that lead to larger multipacting probabilities. We report on simulation results for CYCIAE-100, which gives us an insight view of the multipacting process and help to develop cures to suppress these phenomena.

TU2PB02 11:20 20

The New Axial Buncher at INFN-LNS

A.C. Caruso*, G. Gallo, A. Longhitano (INFN/LNS) F. Consoli (Associazione Euratom-ENEA sulla Fusione) J. Sura (Warsaw University)*

A new axial buncher for the K-800 superconducting cyclotron is under construction at LNS. This new device will replace the present buncher installed along the vertical beam line, inside the yoke of the cyclotron at about half a metre from the medium plane. Maintenance and technical inspection are very difficult to carry out in this situation. The new buncher will still be placed along the axial beam line, just before the bottom side of the cyclotron yoke. It consists of a drift tube driven by a sinusoidal RF signal in the range of 15-50 MHz, a matching box, an amplifier, and an electronic control system. A more accurate mechanical design of the beam line portion will allow for the direct electric connection of the matching box to the ceramic feed-through and drift tube. This particular design will minimize, or totally avoid, any connection through coaxial transmission line. It will reduce the entire geometry, the total RF power and the maintenance. In brief, the new axial buncher will be a compact system including beam line portion, drift tube, ceramic feed-through, matching box, amplifier and control system interface in a single structure.

TU2PB03 11:40 20 **Heat Transfer Study and Cooling of 10 MeV Cyclotron Cavity**

H. Afarideh, ***H. Afarideh***, *G.R. Aslani (AUT) M.R. Asadi (PPRC) M. Ghergherehchi (SKKU)*

The most important problem in mechanical design of RF cavity of cyclotron is generated heat by RF power loss. An optimized cooling system for cavity is necessary to prevent Dee damaging and minimizing error function of cyclotron created by displacements. Also optimization of water circuit and water flow is essential because it affects unwanted vibrations and manufacturing. In this paper an attempt has been done to design an optimized cooling system for the cavity of a 10 MeV cyclotron with frequency of 69 MHz and 50 KW RF power using ANSYS and CST software.

TU2PB04 12:00 20 **Resonator System for the BEST 70 MeV Cyclotron**

V. Sabaiduc, *G. Gold, B.A. Versteeg (BCSI) J. Panama (Best Theratronics Ltd.)*

Best Cyclotron Systems Inc. is presently developing a 70 MeV cyclotron for radioisotope production and research purpose. The RF system comprises two separated resonators driven by independent amplifiers to allow for the phase and amplitude modulation technique to be applied for beam intensity modulation. The resonators are presently in the commissioning phase consisting of cold test measurements followed by high power commissioning in the cyclotron. Preliminary simulation results have been reported and are: 56MHz operation (fourth harmonic, half-wave resonator design), 60 to 70kV dee voltage, quality factor 8000 with the estimated dissipated power of 17kW per resonator. The electromagnetic modeling has been done with CST Microwave Studio. All simulation results showed a very conservative design with typical parameters for the energy and size of the resonators. The paper will present the measurement results on a cold test set-up configuration as well as the commissioning with high power in the cyclotron.

TUPPT — Poster Session: Controls, Diagnostics, Ion Sources, Injection, RF, Vacuum

Cyclotron Subsystems

TUPPT001 **Control System of 10 MeV Baby Cyclotron**
A. Abdorrahman, *H. Afarideh, A. Afshar, G.R. Aslani, S. Malakzade (AUT) M. Ghergherehchi (SKKU)*

TUPPT002 **Simulation of the Vacuum System Operation for Cyclotron Accelerator**
S. Malakzade, *A. Abdorrahman, H. Afarideh, A. Afshar, G.R. Aslani (AUT) M. Ghergherehchi (SKKU)*

TUPPT003 **Control System Conversion of the AGOR Cryo System**
J.E. de Jong, *S. Brandenburg, M.A. Hofstee (KVI)*

TUPPT004 **The Development of Control System for 9 MeV Cyclotron**
Y.S. Lee, *J.-S. Chai, S.Y. Jung, H.S. Kim, H.W. Kim, S.H. Kim, J.C. Lee, S.H. Lee, J.K. Park, S. Shin, H.S. Song, Y.H. Yeon (SKKU) K.-H. Park (PAL)*

TUPPT005 **Temperature Stability of the TRIUMF Cyclotron RF Controls**
M.P. Laverty, *K. Fong, Q. Zheng (TRIUMF)*

TUPPT006 **The Development of Radial Probe for CYCIAE-100**
F.P. Guan, *Z.G. Li, C. Wang, L.P. Wen, H.D. Xie, Z.G. Yin, T.J. Zhang (CIAE)*

TUPPT007 **Design of a Fast Beam Chopper for K-130 Cyclotron Beams Applied to the Characterization of Neutron Detectors**
A. Misra, *A. Chakrabarti, P.S. Chakraborty, P.Y. Nabhiraj (VECC)*

TUPPT008 **A Profile Analysis Method for High-Intensity DC Beams Using a Thermographic Camera**
K. Katagiri, *S. Hojo, T. Honma, A. Noda, K. Noda (NIRS)*

TUPPT009 **Development of Rapid Emittance Measurement System**
K. Kamakura, *M. Fukuda, N. Hamatani, K. Hatanaka, M. Kibayashi, S. Morinobu, K. Nagayama, T. Saito, H. Tamura, H. Ueda, H. Yamamoto, Y. Yasuda, T. Yorita (RCNP)*

TUPPT010 **VARIANTS OF GROUNDING AND SHIELDING IN A BEAM DIAGNOSTICS MEASUREMENT OF LOW SIGNAL CURRENTS**
R. Dölling *(PSI)*

TUPPT011 **Measurement of Turn Structure in the Central Region of the TRIUMF Cyclotron**
T. Planche, *R.A. Baartman, Y.-N. Rao (TRIUMF)*

TUPPT012 **The Design and Experiments of the Axial Injection System for CYCIAE-100 Cyclotron**
H.J. Yao, *T. Ge, Y.L. Lu, C. Wang, T.J. Zhang, X. Zheng (CIAE)*

TUPPT013 **Simulation of Sufficient Spindle Cusp Magnetic Field for 28 GHz ECRIS**
***M.H. Rashid**, A. Chakrabarti (VECC)*

TUPPT014 **Characterization of the Versatile Ion Source (VIS) for the Production of He^{+} and H^{2} Beams**
***L. Celona**, L. Calabretta, G. Castro, G. Ciavola, S. Gammino, D. Mascali, G. Torrisi (INFN/LNS) G. Castro (Universita Degli Studi Di Catania) F. Di Bartolo (INFN & Messina University)*

TUPPT015 **A Center Region Upgrade of the LBNL 88-Inch Cyclotron**
***K. Yoshiki Franzen**, J.Y. Benitez, M.K. Covo, A. Hodgkinson, C.M. Lyneis, B. Ninemire, L. Phair, P. Pipersky, M.M. Strohmeier, D.S. Todd (LBNL) D. Leitner (NSCL)*

TUPPT016 **Developments of Ion Source Complex for Highly Intense Beam at RCNP**
***T. Yorita**, M. Fukuda, K. Hatanaka, K. Kamakura, S. Morinobu, H. Ueda, Y. Yasuda (RCNP)*

TUPPT018 **CRITICAL ANALYSIS OF NEGATIVE HYDROGEN ION SOURCES FOR CYCLOTRONS**
***S. Korenev** (Siemens Medical Solutions Molecular Imaging)*

TUPPT019 **Design Study of Penning Ion Source for Compact 9 MeV Cyclotron**
***Y.H. Yeon**, J.-S. Chai, T.V. Cong, Kh.M. Gad, M. Ghergherehchi, H.S. Kim, H.W. Kim, S.H. Kim, S.H. Lee, Y.S. Lee, S.Y. Oh (SKKU)*

TUPPT020 **Simulation of Hydrogen Plasma for a compact Negative Hydrogen Penning Ion Source**
***Y.H. Yeon**, J.-S. Chai, Kh.M. Gad (SKKU)*

TUPPT022 **A High Current H^{-} Cusp Ion Source at TRIUMF**
***K. Jayamanna**, I.V. Bylinskii, G. Cojocaru, W. L. Louie, M. Minato, S. Saminathan (TRIUMF)*

TUPPT023 **Design and Simulation of Cavity for 10 MeV Compact Cyclotron**
***V. Afzalan**, H. Afarideh, R. Azizi (AUT) M. Ghergherehchi (SKKU)*

TUPPT024 **Design of a Digital Low-Level RF System for BEST Medical Cyclotrons**
***G. Gold**, V. Sabaiduc (BCSI)*

TUPPT025 **Resonator System for the BCSI Test Stand Cyclotron**
***G. Gold**, V. Sabaiduc, J. Zhu (BCSI) L. AC. Piazza (INFN/LNL)*

TUPPT026 **The Design and Testing of an Automatic RF Conditioning System for the Compact Medical Cyclotron**
***Y. Lei**, B. Ji, P.Z. Li, C. Wang, Z.G. Yin, T.J. Zhang (CIAE)*

TUPPT028 **Development of 20kW RF Amplifier for Compact Cyclotron**
***S.H. Lee**, J.-S. Chai, H.S. Kim, Y.S. Lee, H.S. Song, C.V. Truong, Y.H. Yeon (SKKU) J.H. Kim (KIRAMS)*

TUPPT029 **Design Study of a 83.2 MHz RF Cavity for the 9 MeV Compact Cyclotron**
S. Shin, *J.-S. Chai, J.C. Lee (SKKU) B.N. Lee (KAERI)*

TUPPT030 **Development of 1.5 kW RF Driver for Compact Cyclotron**
H.S. Song, *J.-S. Chai, T.V. Cong, S.H. Lee, Y.S. Lee, S. Shin (SKKU) J.H. Kim (KIRAMS)*

TUPPT031 **TRIUMF's Cyclotron Vacuum System: Status and Upgrades**
D. Yosifov, *I.V. Bylinskii, A. Koveshnikov (TRIUMF)*

TUPSH — Poster Session: Strippers, Extraction, Magnets, Beam Transport

Cyclotron Subsystems

TUPSH002 **Design and Construction of Combination Magnet for CYCIAE-100**
S.M. Wei, *Shizhong. An, M. Li, C. Wang, M. Yin, T.J. Zhang, X. Zheng, J.Q. Zhong (CIAE)*

TUPSH003 **High Power Proton Beam Extraction of an 800 MeV Cyclotron**
M. Li, *C. Wang, J.J. Yang, T.J. Zhang, J.Q. Zhong (CIAE)*

TUPSH005 **Investigation of Cyclotron Carbon Foil Lifetime in Relation to its Thickness**
J.-W. Kim, *S. Hong, J.H. Kim (IBS) Y. Choi (Dongguk University) Y.-S. Kim (Energy & Environmental System)*

TUPSH006 **Development of a New Active-Type Gradient Corrector for an AVF Cyclotron**
M. Fukuda, *N. Hamatani, K. Hatanaka, K. Kamakura, S. Morinobu, K. Nagayama, T. Saito, H. Tamura, H. Ueda, Y. Yasuda, T. Yorita (RCNP)*

TUPSH007 **Improvement in Design Study of 10 MeV AVF Cyclotron Magnet**
R. Solhju, *H. Afarideh, B. Mahdian (AUT) J.-S. Chai, M. Ghergherehchi (SKKU)*

TUPSH008 **Conceptual Design of the 100 MeV Separated Sector Cyclotron**
B. Mahdian, *H. Afarideh (AUT) J.-S. Chai, M. Ghergherehchi (SKKU)*

TUPSH009 **Magnetic Field Mapping of the Best 70 MeV Cyclotron**
F.S. Grillet, *B.F. Milton (BCSI) D.T. Montgomery (Cedarflat Precision Inc.)*

TUPSH011 **Developments of HTS Magnets at RCNP**
K. Hatanaka, *M. Fukuda, K. Kamakura, S. Takemura, H. Ueda, Y. Yasuda, K. Yokoyama, T. Yorita (RCNP) T. Kawaguchi (KT Science Ltd.)*

TUPSH012 **The Development of High Stability Magnet Power Supply**
K.-H. Park, *H.S. Han, Y.-G. Jung, D.E. Kim, S.-C. Kim, H.-G. Lee, H.S. Suh (PAL) J.-S. Chai, Y.S. Lee (SKKU)*

TUPSH013 **Design Study of 10 Mev Cyclotron Magnet for PET**
H.S. Kim, *J.-S. Chai, M. Ghergherehchi, H.W. Kim (SKKU)*

TUPSH014 **An Integrated Self-Supporting Mini-Beamline for PET Cyclotrons**
M.P. Dehnel, *D.E. Potkins, T.M. Stewart (D-Pace)*

TUPSH015 **Energy Selection System Design for Carbon Therapy Complex**
***G. Hahn**, D.H. An (KIRAMS)*

TUPSH016 **Trim Coil Unbalance of the 88-Inch Cyclotron**
***M. Kireeff Covo**, B. Bingham, C.M. Lyneis, B. Ninemire, L. Phair, P. Pipersky, A. Ratti, M.M. Strohmeier, D.S. Todd (LBNL) K.Y. Franzen (Mevion)*

TU3PB — Diagnostics, Strippers, Extraction

Chair: H.W. Zhao (IMP)

TU3PB01 15:00 30

Bunch-Shape Measurements at PSI's Highpower Cyclotrons and Proton Beam Lines

R. Dölling *(PSI)*

We have measured the 2D bunch shapes in the radial-longitudinal plane of individual turns in the Injector 2 cyclotron. We describe the motivation for the measurements, the hardware used and the measurement results. The additional benefit of obtaining a reference for the standard differential radial probe measurement is discussed as well.

TU3PB02 15:30 20

Development of a Fiber-Optical Radial Ion Beam Profile and Position Monitor for the 88-Inch Cyclotron at LBNL

M.M. Strohmeier*, J.Y. Benitez, C.M. Lyneis, L. Phair, P. Pipersky, D.S. Todd (LBNL) K.Y. Franzen (Mevion)*

Operators at the 88-Inch Cyclotron have many tuning parameters to optimize transmission from injection through extraction. However, the only diagnostics they have had were a Faraday Cup at the exit of the machine and a so called "Dee-Probe" which gives a current-vs-radius (IvR) measurement. Motivated by low transmission of the Cyclotron and to address how tuning can affect the beam, we have developed an optical beam viewer whose radial position within the cyclotron can be adjusted remotely. This viewer allows us to image the beam cross section and its axial position with very high spatial resolution as a function of radius. In this paper, we describe the mechanical development of the device which consists of a Kbr scintillator crystal, a fiber bundle and a digital camera and we present data from its initial commissioning.

TU3PB03 15:50 30

R&D of Helium Gas Stripper for Intense Uranium Beams

H. Imao *(RIKEN Nishina Center)*

Intensity upgrade of uranium beams is one of the main concerns at the RIKEN Radioactive Isotope Beam Factory (RIBF). The lifetime problem of carbon-foil strippers due to the high energy loss of uranium beams around 10~MeV/u was a principal bottleneck for the intensity upgrade in the acceleration scheme at the RIBF. We have developed a re-circulating He-gas stripper as an alternative to carbon foils for the acceleration of high-power uranium beams. The new stripping system was actually operated in user runs with U^{35+} beams of more than 1 puA. Electron-stripped U^{64+} beams were stably delivered to subsequent accelerators without serious deterioration of the system for six weeks. The new He-gas stripper, which removed the primary bottleneck in the high-intensity uranium acceleration, greatly contributed the tenfold increase of the average output intensity of the uranium beams from the previous year.

TU3PB04
16:20 20

TRIUMF Extraction Foil Developments and Contamination Reduction

***Y.-N. Rao**, R.A. Baartman, I.V. Bylinskii, V.A. Verzilov (TRIUMF)*

We made important developments on the extraction probes and stripping foils at TRIUMF. One of the issues we had was related to the beam spills. We can only tolerate beam losses of about 1 nA/meter in the primary beamlines. This is 10^{-5} level at 100uA. Beam spills are primarily due to the large angle scattering from the stripper foil. In order to minimize the scattering, it was suggested that 2.5 to 5 times thinner foils be used. Another issue was that foils deformed or even cracked during use in the past. This was caused by a temperature rise in the foil frame. Concerning these 2 issues, improvements were made such that (1) highly-orientated pyrolytic graphite foils, of thickness about 2mg/cm^2 are now used; (2) Tantalum frame with a thin copper cushion is now used in place of the previous stainless steel as Tantalum has better thermal conductivity. As a result of these improvements, we have achieved 4 times longer lifetime with the foils. Moreover, the Be-7 contamination surveyed at the extraction probe has been reduced by a factor of 5 to 10. This paper presents these developments and outcomes, including the simulation and calculations made.

TU4PB — Magnets

Chair: Y. Jongen (IBA)

TU4PB01 17:10 20

Mapping of the New IBA Superconducting Synchrocyclotron (S2C2) for Proton Therapy

***V. Nuttens**, W.J.G.M. Kleeven, C. L'Abbate, **V. Nuttens**, Y. Paradis (IBA) M. Conjat, J. Mandrillon, P. Mandrillon (AIMA)*

The magnetic field in the Superconducting Synchrocyclotron (S2C2) has been measured with a newly developed mapping system during the commissioning of the machine at IBA. The major difference with other mapping systems at IBA is the usage of a search coil, which provides high linearity over a large magnetic field range and the possibility to measure in a more time economic way. The first mapping results of the S2C2 were compared with OPERA3D calculations. The average field, the tune functions and the first harmonic were the main quantities which were compared and showed good agreement with the model. For example, the average field was within 0.3% of the calculation over the entire machine. In order to assess the efficiency of the regenerative extraction mechanism, protons were tracked in the measured map up to extraction. The horizontal position of the main coil was found to be a crucial parameter for the optimization of the extraction. A dedicated linear mapping system consisting of 7 Hall probes was positioned in the extraction channel of the S2C2. The field values from this linear mapping system were used to assess the optics of the beam exiting the S2C2.

TU4PB02 17:30 20

Structural and Magnetic Properties of Pure Iron Cast for Cyclotrons

***S. Zaremba**, **S. Zaremba** (IBA) E. Ferrara, F. Fiorillo, L. Martino, E. Olivetti, L. Rocchino (INRIM)*

At IBA, the steels used to build the magnets of the Cyclone 230 are cast on demand, using very strict criteria, casting procedure, requirements and quality control. Among the various steps performed at the foundry, a thermal annealing is made. In this work, we assess the usefulness of such thermal treatment. In this communication, samples of pure iron cast ingots (maximum concentration of C = 31 ppm, N = 94 ppm, O = 31 ppm, S = 65 ppm) have been magnetically and structurally characterized. Progressive magnetic softening was observed upon successive annealing steps. These changes of the magnetic properties were ascribed to the relief of internal stresses. Various results, obtained by means of X-ray diffraction, electron microscope and precise determination of magnetization curve and hysteresis loop, will be presented and commented.

TU4PB03 17:50 20

Superconducting Beam Transport Channel for a Strong-Focusing Cyclotron

***J.N. Kellams**, S. Assadi, K.C. Damborsky, P.M. McIntyre, K.E. Melconian, N. Pogue, A. Sattarov (Texas A&M University)*

A superconducting strong focusing cyclotron is being developed for high current applications. Alternating-gradient focusing is provided by an array of ~ 6T/m superconducting beam transport channels which lie in the sectors along the arced beam trajectory of each orbit of the cyclotron. The ~1T sector dipoles, corrector dipoles, and Panofsky type quadrupoles utilize MgB2 superconductor operating in the range 15-20 K. The quadrupole windings make it possible to produce strong focusing of the transverse phase space throughout acceleration. The trim dipole makes it possible to maintain isochronicity and to open the orbit spacing at injection and extraction. The design, development and prototype progress will be presented.

TU4PB04 18:10 20

Methods of Increasing Accuracy in Precision Magnetic Field Measurements of Cyclotron Magnets

***N.V. Avreline**, W. Gyles, R.L. Watt (ACSI)*

A new magnetic field mapper was designed and developed to provide increased accuracy of cyclotron magnetic field measurements. This mapper was designed for mapping the magnetic fields of TR-19, TR-24, and TR-30 cyclotron magnets manufactured by Advanced Cyclotron Systems Inc. A Group3 DTM-133 Hall Probe (HP) with measurement range from 2 Gauss to 21 kGauss was used in the mapper design. Use of a fast ADC NI9239 module and error reduction algorithms, based on a polynomial regression method, allowed the reduction of noise to 0.5 Gauss. The HP arm was made as a carbon fibre foam sandwich. This rigid structure kept the HP in a flat plane within 0.05mm. In order to measure a high gradient field, the design of this mapper provided a higher resolution of HP arm angle, within 0.0005^{o}, and radial positioning, within 0.05mm. A NI cDAQ-9188 CompactDAQ Ethernet chassis with five modules was used as the main interface between the CPU and the sensors and actuators. The main part of the code was written in LabVIEW 2011, which allowed control of all actuators and sensors, and to carry out live data processing. The mapper was successfully used to map TR-19 and TR-24 cyclotron magnets.

WE1PB — Small Cyclotrons for Demo & Education

Chair: T.W. Koeth (UMD)

WE1PB01 08:30 30 **The Houghton College Cyclotron: a Tool for Educating Undergraduates**

M.E. Yuly *(Houghton College)*

The cyclotron is an ideal undergraduate research project because its operation and use involve so many of the principles covered in the undergraduate physics curriculum – from resonant circuits to nuclear reactions. The physics program at Houghton College, as part of an emphasis on active learning, requires all majors to complete a multiyear research project culminating in an undergraduate thesis. Over the past ten years seven students have constructed a working 1.2 T tabletop cyclotron theoretically capable of producing approximately 400 keV protons. The construction and performance of the cyclotron will be discussed, as well as its use as an educational tool.

WE1PB02 09:00 30 **The Rutgers Cyclotron: Placing Student's Careers on Target**

K.J. Ruisard *(Rutgers University, The State University of New Jersey) G.A. Hine, T.W. Koeth (UMD) A.J. Rosenberg (Stanford University)*

The Rutgers 12" Cyclotron is an educational tool used to introduce students to the multifaceted field of accelerator physics. Designed for the production of 1 MeV protons, the cyclotron was first conceived in 1995 by two Rutgers undergraduates. Since its inception, the cyclotron has been under continuous development and is currently incorporated into the modern physics instructional lab at Rutgers University, as a semester-long mentored project. Students who participate in the cyclotron project receive an introduction to accelerator physics topics such as high voltage power, RF systems, vacuum systems and magnet operation. Students also learn basic beam physics concepts, including betatron motion and conservation of emittance. The Rutgers Cyclotron is often a student's first encounter with an accelerator, and to date, 5 of the 15 participants have moved on to careers in the accelerator field.

WE1PB03 09:30 20 **COLUMBUS a Small Cyclotron for School- and Teaching Purposes**

C.R. Wolf *(FZJ) M. J. Frank, E. Held (Ernes)*

A small cyclotron has been constructed for school- and teaching purposes. The cyclotron uses a water-cooled magnet with adjustable pole-pieces. The magnet provides a field up to 0,7 T. Between the two poles the vacuum chamber is positioned. The vacuum chamber provides ports for the different subsystems, measuring tools and some viewports. A turbo molecular pump backed up by a dry compressor vacuum pump is used to evacuate the chamber to a pressure of 10^{-5} mbar. The ions will be accelerated between two brass RF electrodes, called dee and dummy-dee. In the center of the chamber there is a thermionic ion source. A massflow controller fills it with hydrogen gas ionized by electrons from a cathode. The required 5,63 MHz RF power is supplied by a RF transceiver. A matchingbox adjusts the output impedance of the transceiver to the input impedance of the cyclotron. The expected final energies of the protons are 24 keV after 12 revolutions. At these energies there is no radiation outside the chamber. In addition to the design of this cyclotron it is the purpose of this dissertation to use standard devices to realize a low-cost solution.

WE1PB04 09:50 20 **A Novel Optical Method for Measuring Beam Phase and Width in the Rutgers 12-Inch Cyclotron**

J.L. Gonski, *S. Burcher,* ***J.L. Gonski*** *(Rutgers University, The State University of New Jersey) B.L. Beaudoin (UMD)*

We present an experimental longitudinal measurement of beam and phase slippage as a function of magnetic field deviation in a weak focusing field, using proton acceleration data from the Rutgers 12-inch cyclotron. A gated camera was used to determine beam arrival time from the radiation emitted by a fast ZnO:Ga doped phosphor target when struck by accelerated protons. Images integrated light emitted in 9 degree increments over a full 360-degree RF cycle. Analysis of relative image brightness allowed for the successful acquisition of relative phase shift and azimuthal beam width over several magnetic field strengths. Theoretical predictions and simulation via Poisson Superfish and SIMION software show good agreement with data, validating the optical method for qualitative measurements. This new method is independent of dee voltage and allows for measurements to be taken in the central region of the cyclotron, where other electrically based methods of measurement are challenging due to high RF electric fields. Such characteristics validate the use of gated camera imaging for cyclotron research, and motivate future refinement of this technique for a variety of studies.

WE1PB05 10:10 20 **"The Cyclotron Kids" 2 MeV Proton Cyclotron**

H. Baumgartner *(MIT)*

Two high school students (the "Cyclotron Kids") decided they wanted to build a small cyclotron by themselves in 2008. After researching and designing on their own, they looked for a way to fund their science project. After the students sent out tens of letters looking for sponsors, Jefferson Lab replied, offering funding and mentorship. Over several summers, the students worked at Jefferson Lab to take the cyclotron from the drawing board to near-completion. The cyclotron is now at Old Dominion University, where it will be used as an educational tool in the accelerator physics program.

18-Sep-13 11:00 – 12:30	Pinnacle Ballroom

WE2PB — Space Charge

Chair: S. Brandenburg (KVI)

WE2PB01 11:00 30

Review of Space Charge Effects in Cyclotrons

R.A. Baartman *(TRIUMF)*

A review will be given of the intensity limits of cyclotrons due to space charge, both longitudinal and transverse.

WE2PB02 11:30 30

Vlasov Equation Approach to Space Charge Effects in Isochronous Machines

A.J. Cerfon *(Courant Institute of Mathematical Sciences, New York University)*

Starting from the collisionless Vlasov equation, we derive two simple coupled two-dimensional fluid equations describing the radial-longitudinal beam vortex motion associated with space charge effects in isochronous cyclotrons. These equations show that the vortex motion can be intuitively understood as the nonlinear advection of the beam by the ExB velocity field, where E is the electric field due to the space charge and B is the applied magnetic field. This explains why elongated beams develop spiral halos while round beams are always stable. Solving the coupled equations numerically, we find good agreement between our model and 3-D Particle-In-Cell OPAL simulations*.

* J.J. Yang, A.Adelmann, M. Humbel, M. Seidel, and T.J. Zhang, Physical Review Special Topics Accelerators and Beams 13, 062401 (2010)

WE2PB03 12:00 30

Transverse-Longitudinal Coupling by Space Charge in Cyclotrons

C. Baumgarten *(PSI)*

Based on a linear space charge model and on the results of PIC-simulations with OPAL, we analyze the conditions under which space charge forces support bunch compactness in high intensity cyclotrons and/or FFAGs. For this purpose we compare the simulated emittance increase and halo formation for different matched and mismatched particle distributions injected into a separate sector cyclotron with different phase curves.

18-Sep-13 13:30 – 15:00 Pinnacle Three

WEPPT — Poster Session: Beam Dynamics, Small cyclotrons, High Intensity

Beam Dynamics

WEPPT001 **Study of the Buncher NB1 and NB2**
X.N. Li *(IMP)*

WEPPT002 **Optimizing the Accelerated Parameters of the SFC by Using PSO Algorithm**
L.T. Shi *(IMP)*

WEPPT003 **Beam Optical Simulation in a Proposed Magnetic Einzel Lens**
M.H. Rashid*, A. Chakrabarti (VECC)*

WEPPT004 **Feasibility Study of Intense Beam Matching at the Spiral Inflector Using Elliptical Solenoid**
A. Goswami*, V.S. Pandit, P. Sing Babu (VECC)*

WEPPT005 **Emittance Measurements at the Strasbourg TR24 Cyclotron for the Addition of a 65 MeV Linac Booster**
A. Degiovanni*, U. Amaldi, S. Benedetti, D. Bergesio, A. Garonna, G. Molinari (TERA) S. Braccini, E.V. Kirillova (LHEP) D. Brasse, M. Pellicioli, M. Rousseau, J. Schuler (IPHC) R.L. Watt, E. van Lier (ACSI)*

WEPPT006 **Design of Achromatic Bends for the High Energy Beam Transport System of HCI at IUAC Delhi**
A. Mandal*, D. Kanjilal, S. Kumar, G.O. Rodrigues (IUAC)*

WEPPT007 **Formation of 2D Uniform Ion Distribution by Octupole Magnets in U-400M Cyclotron**
I.A. Ivanenko*, I.V. Kalagin, V.I. Kazacha, N.Yu. Kazarinov (JINR)*

WEPPT008 **The Correction of Vertical Shifting of the Extracted Beam at the Test Operation of DC-110 Cyclotron**
I.A. Ivanenko*, B. Gikal, I.V. Kalagin, N.Yu. Kazarinov, V.I. Mironov, E. Samsonov (JINR)*

WEPPT009 **Transverse Phase-Space Distributions of Low-Energy Ion Beams**
S. Saminathan *(TRIUMF) J.P.M. Beijers, S. Brandenburg, H.R. Kremers, V. Mironov (KVI)*

WEPPT011 **Measurement of Radial Coherent Oscillation and Phase of Accelerating Beam**
J. Pradhan*, U. Bhunia, A. Chakrabarti, J. Debnath, M.K. Dey, A. Dutta, Z.A. Naser, S. Paul, V. Singh (VECC)*

WEPPT012 **Beam Dynamics in Presence of Imperfection Fields Near the Extraction Zone of Kolkata Superconducting Cyclotron**
J. Debnath, *U. Bhunia, A. Chakrabarti, M.K. Dey, A. Dutta, Z.A. Naser, S. Paul, J. Pradhan, V. Singh (VECC)*

WEPPT013 **Measurement and Analysis of Beam Behavior at the Central Region of Kolkata Superconducting Cyclotron**
A. Dutta, *A. Agarwal, U. Bhunia, J. Debnath, M.K. Dey, Z.A. Naser, S. Paul, J. Pradhan, V. Singh (VECC)*

WEPPT014 **Analysis of Phase Bunching in the Central Region at the JAEA AVF Cyclotron**
N. Miyawaki, *H. Kashiwagi, S. Kurashima, S. Okumura (JAEA/TARRI) M. Fukuda (RCNP)*

WEPPT015 **Study of Beam Capture in Compact Synchrocyclotron**
S.A. Kostromin, *G.A. Karamysheva, N.A. Morozov, E. Samsonov (JINR)*

WEPPT016 **Enhancing the Performance of a Typical Compact Cyclotron**
P. Schmor *(SPAC)*

WEPPT017 **Beam Trajectory Calculation for a 9MeV Cyclotron**
S.Y. Jung, *J.-S. Chai, J.-S. Chai, H.W. Kim, S.H. Kim, Y.S. Lee (SKKU)*

WEPPT018 **Behavior of Space Charge Dominated Beam Envelope in Central Region of High Current Cyclotron**
R. Azizi, *H. Afarideh, V. Afzalan (AUT) M. Ghergherehchi (SKKU)*

WEPPT019 **Investigation on the Transverse Emittance Growth of Intense Beam during Bunching**
P. Sing Babu, *A. Goswami, V.S. Pandit (VECC)*

WEPPT020 **New Features in OPAL**
A. Adelmann *(PSI)*

Small Cyclotrons for Education

WEPPT021 **A Simple Ion Source for a Cyclotron**
M. J. Frank, *M. Schlosser (Ernes)*

WEPPT022 **A Simple RF-System**
E. Held, *M. J. Frank (Ernes)*

WEPPT023 **Proton Beam Studies in Rutgers 12-Inch Cyclotron**
M. Atay *(Koc University)*

WEPPT024 **The Rutgers 12-Inch Cyclotron: Dedicated to Training Through R&D**
T.W. Koeth, *J.E. Krutzler, T.S. Ponter, W.S. Schneider (Rutgers University, The State University of New Jersey) D.E. Hoffman (PU)*

WEPPT025 **Beam Physics Demonstrations with the Rutgers 12-Inch Cyclotron**
T.W. Koeth *(UMD)*

WEPPT026 **Cyclotron Injection Tests of High Intensity H_2^+ Beam**
F.S. Labrecque, *B.F. Milton (BCSI) J.R. Alonso, A. Calanna, D. Campo, J.M. Conrad, M. Toups (MIT) L. Calabretta, L. Celona (INFN/LNS) D. Winklehner (NSCL) L.A. Winslow (UCLA)*

WEPPT027 **Design of the Injection Line into the INFN Molecular H_2^+ 800 MeV High Power Cyclotron**
M. Haj, *F. Méot (BNL) L. Calabretta (INFN/LNS) A. Calanna (CSFNSM)*

WEPPT028 **Proposal for Cyclotron Test Site Catania**
L. Calabretta, *D. Campo (INFN/LNS) J.R. Alonso, W.A. Barletta, A. Calanna, D. Campo, J.M. Conrad (MIT) L. AC. Piazza (INFN/LNL) M. Shaevitz (Columbia University)*

WEPPT029 **The Cyclotron Complex for the DAEδALUS Experiment**
A. Calanna, *J.R. Alonso, D. Campo, J.M. Conrad (MIT) A. Adelmann (PSI) L. Calabretta (INFN/LNS) V. Fishman, C.E. Miller, J.V. Minervini, A. Radovinsky, B.A. Smith (MIT/PSFC) J.J. Yang (CIAE)*

WEPPT030 **High Intensity Compact Cyclotron for ISODAR Experiment**
D. Campo, *J.R. Alonso, W.A. Barletta, L.M. Bartoszek, A. Calanna, J.M. Conrad, M. Toups (MIT) A. Adelmann (PSI) L. Calabretta (INFN/LNS) M. Shaevitz (Columbia University) L.A. Winslow (UCLA) J.J. Yang (CIAE)*

WEPPT031 **High Intensity Beam Study in KURRI FFAGs**
S. Machida, *C. Gabor, D.J. Kelliher, C.R. Prior, C.T. Rogers, S.L. Sheehy (STFC/RAL/ASTeC) Y. Ishi, J.-B. Lagrange, Y. Mori, T. Uesugi (Kyoto University, Research Reactor Institute)*

WEPSH — Poster Session: Applications - Medical

Applications

WEPSH001 **Monte Carlo FLUKA Code Simulation for Study of Ga-68 Production by Direct Proton-Induced Reaction**
M. Sadeghi *(Agricultural, Medical & Industrial Research School) M. Aboudzadeh (Nuclear Science & Technology Research Institute) L. Mokhtari (Zanjan University)*

WEPSH002 **Investigation of Transmutation Adiabatic Resonance Crossing in 99Mo Production**
M. Sadeghi *(Agricultural, Medical & Industrial Research School) A. Khorshidi, A. Pazirandeh (PPRC)*

WEPSH003 **Development of New Combined System for Production of FDG and NaF Radiopharmacuticals**
F. Dehghan*, H. Afarideh, S. Jaloo (AUT) M. Ghergherehchi (SKKU)*

WEPSH006 **62 Zn Radioisotope Production by Cyclotron Accelerator**
M. Ghergherehchi*, J.-S. Chai, J.-S. Chai (SKKU) H. Afarideh (AUT)*

WEPSH007 **Radiochromic Film as a Dosimetric Tool for Low Energy Proton Beams**
S. Devic *(Affiliation Request Rejected) S. Aldelaijan, F.M. Alrumayan, M. Shehadeh (King Faisal Specialist Hospital and Research Centre) B. Moftah (Belal Moftah, PhD)*

WEPSH008 **Characterization of the CS30 Cyclotron at KFSH&RC for Radiotherapy Applications**
B. Moftah *(Belal Moftah, PhD) S. Aldelaijan, F.M. Alrumayan, F. Alzorkani, M. Shehadeh (King Faisal Specialist Hospital and Research Centre) S. Devic (Affiliation Request Rejected)*

WEPSH009 **Production of Secondary Neutrons from Patients During Hadron Therapy: Their Potential Radiation Risks and the Concept of Compromise Optimum Incident Energy**
M.A. Chaudhri *(Inst. of Biomaterials, Uni. of Erlangen-Nuernberg)*

WEPSH010 **Proton Therapy at the Institut Curie – CPO: Operation of an IBA C235 Cyclotron Looking Forward Scanning Techniques**
A. Patriarca*, S.J. Meyroneinc (Institut Curie - Centre de Protonthérapie d'Orsay)*

WEPSH012 **Design Studies of 70 MeV Synchrocyclotron for Proton Therapy**
G.A. Karamysheva*, S.A. Kostromin, N.A. Morozov, E. Samsonov (JINR) S.N. Dolya (JINR/DLNP)*

WEPSH013 **The Paul Scherrer Institute (PSI) Upgrades the Existing Proton Therapy Facility PROSCAN, Based on the Superconducting Cyclotron COMET as the Proton Source, with a Third Irradiation Facility, Gantry 3**

J.P. Duppich*, C. Baumgarten, R. Koeferli, D. Meer, J.M. Schippers (PSI)*

WEPSH043 **Performance of IBA New Conical Shaped Niobium [18O]Water Targets**

F.G. Devillet*, J. Courtyn, J.-M. Geets, M. Ghyoot, E.K. Kral, O. Michaux, B. Nactergal (IBA) R. Mooij, L.R. Perk (BV Cyclotron VU)*

WE3PB — Space Charge, Particle Dynamics

Chair: T.J. Zhang (CIAE)

WE3PB01 15:00 30 **Experimental Study of Resonance Crossing with a Paul Trap**

H. Sugimoto *(KEK)*

The effect of resonance crossing on beam stability is studied systematically by employing a novel tabletop experimental tool and a multiparticle simulation code. A large number of ions are confined in a compact linear Paul trap to reproduce the collective beam behavior. We can prove that the ion plasma in the trap is physically equivalent to a charged-particle beam propagating through a strong focusing channel. The plasma confinement force is quickly ramped such that the trap operating point traverses linear and nonlinear resonance stop bands as in cyclotrons and FFAGs.

WE3PB02 15:30 20 **Improvement of the Current Stability from the TRIUMF Cyclotron**

T. Planche*, R.A. Baartman, Y.-N. Rao (TRIUMF)*

The $\nu_r = 3/2$ resonance, driven by the third harmonic of the magnetic gradient errors, causes modulation of the radial beam density in the TRIUMF cyclotron. Since extraction is by H^- stripping, this modulation induces unwanted fluctuations of the current split between the two high-energy beam lines. To compensate field imperfections, the cyclotron has sets of harmonic correction coils at different radii, each set constituted of 6 pairs of coils placed in a 6-fold symmetrical manner. The 6-fold symmetry of this layout cannot create a third harmonic of arbitrary phase, and so a single set of harmonic coils cannot provide a full correction of third harmonic errors driving the $\nu_r = 3/2$ resonance. However, the outermost two sets of harmonic correction coils are azimuthally displaced. We took advantage of it to achieve a full correction of the resonance. This greatly improved the beam current stability in the high-energy beam lines. To further improve the current stability in the high-energy beam lines, we implemented an active feedback system. This feedback system acts on the amplitude of the first harmonic Bz correction produced by outermost set of harmonic coils.

WE3PB03 15:50 20

Space Charge Compensation Measurements in the Injector Beam Lines of the NSCL Coupled Cyclotron Facility

__D. Winklehner__, D.G. Cole, D. Leitner, G. Machicoane, L. Tobos (NSCL)

Space charge compensation is a well-known phenomenon for high current injector beam lines. For beam lines using mostly magnetic focusing elements and for pressures above 10^{-6} mbar, compensation (neutralization) up to 98% has been observed. However, due to the low pressures required for the efficient transport of high charge state ions, ion beams in ECR injector lines are typically only partly neutralized and space charge effects are present. With the dramatic performance increase of the next generation Electron Cyclotron Resonance Ion Sources (ECRIS) it is possible to extract tens of mA of beams from ECR plasmas. Realistic beam transport simulations are important to meet the acceptance criteria of subsequent accelerator systems and have to include non-linear effects from space charge, but also space charge compensation. In this contribution we report on measurements of space charge compensation in the ECRIS low energy beam lines of the Coupled Cyclotron Facility at NSCL using a retarding field analyzer. Results are discussed and compared to simulations.

WE3PB04 16:10 20

Transmission of Heavy Ion Beams in the AGOR Cyclotron

__A. Sen__, S. Brandenburg, M.A. Hofstee (KVI) M.J. van Goethem (UMCG)

During the acceleration of intense low energy heavy ion beams in the AGOR cyclotron feedback between beam intensity and pressure, driven by beam loss induced desorption, is observed. This feedback limits the attainable beam intensity. Calculations and measurements of the pressure dependent transmission for various beam agree reasonably well. Calculation of the trajectories of ions after a charge change shows that the desorption is mainly due to ions with near extraction energies, hitting the outer wall at a shallow angle of incidence. For heavy ions like $206Pb^{27+}$ several charge exchanges are needed before the orbit becomes unstable. Our calculations indicate that these ions make thousands of turns before finally hitting the wall. They therefore are a large fraction of the circulating ions and may contribute to vacuum degradation through restgas ionization. Ion induced desorption for relevant ions and materials has been measured; it explains the observations in the cyclotron semiquantitatively.

WE4PB — Particle Dynamics, Tracking

Chair: H. Schweickert (ZAG)

WE4PB01 17:00 20

Tracking in a Cyclotron with Geant4

F.W. Jones, T. Planche, Y.-N. Rao (TRIUMF)

Building on its precursor GEANT, the tracking and simulation toolkit Geant4 has been conceived and realised in a very general fashion, with much attention given to the modeling of electric and magnetic fields and the accuracy of tracking charged particles through them. As evidenced by the G4Beamline application, Geant4 offers a unique simulation approach to beam lines and accelerators, in a 3D geometry and without some of the limitations posed by conventional optics and tracking codes. Here we apply G4Beamline to the TRIUMF cyclotron, describing the generation and input of the field data, accuracy of closed orbits, stability of multi-turn tracking, tracking accelerated orbits, and phase acceptance. Geant4's 3D visualization tools allow detailed examination of trajectories as well as a particle's-eye view of the acceleration process.

WE4PB02 17:20 20

An All-Purpose 6-D Tracking Code, Zgoubi

F. Méot (BNL)

The ray-tracing code Zgoubi* has long been 6D-tracking through all possible types of fixed field rings**, including, recently, 6D transmission from injection-up to extraction-down in high power cyclotrons in the frame of ADS-Reactor R/D. This is to be added to the long exploited many other capabilities of the code as spin transport, in-flight decay, synchrotron radiation energy loss, etc. An overview will be given, including recent space-charge developments, with illustration including recent high power cyclotron applications.

* `http://sourceforge.net/projects/zgoubi/`, `http://www.osti.gov/bridge/basicsearch.jsp`

** 6-D beam dynamics simulations in FFAGs, F. Meot, ICFA Beam Dyn. Newslett.43:44-50 (2007)

WE4PB03
17:40 20

Optimizing the Radioisotope Production with a Weak Focusing Cyclotron

***C. Oliver**, P. Arce, L. García-Tabarés, D. Gavela, A. Guirao, J.I. Lagares, J. Munilla, D. Obradors-Campos, J.M. Perez Morales, I. Podadera, E. Rodriguez, F. Sansaloni, F. Toral, C. Vázquez (CIEMAT)*

A classical weak focusing cyclotron can result in a simple and compact design for the radioisotope production for medical applications. Two main drawbacks arise in this type of machine. The energy limit imposed by the non RF-particle isochronism requires a careful design of the acceleration process, resulting in challenging requirements for the RF system. On the other hand, the weak focusing forces produced by the slightly decreasing magnetic field make essential to model the central region of the machine to improve the electric focalization with a reasonable phase acceptance. A complete analysis of the different beam losses, including vacuum stripping, has been performed. The main cyclotron parameters have been obtained by balancing the maximum energy we can obtain and the maximum beam transmission, resulting in an optimum radioisotope production.

TH1PB — High Intensity, Applications

Chair: R. Gebel (FZJ)

TH1PB01 08:30 30

Operational Experience at the Intensity Limit in Compact Cyclotrons

***G. Cojocaru**, J.C. Lofvendahl (TRIUMF)*

Compact cyclotrons are a cost-efficient choice for medical radioisotope production since negative hydrogen ions can be used at energies well below 100MeV. The stripping extraction technique allows quite large circulating currents without the need for separated turns. Space charge limits are in the range of 1 to 2 mA, but operating for long periods at these levels is a challenge for many reasons, among them being the sputtering of metal surfaces where unaccepted beam is deposited. These limits and others observed during our 22 years of 24hours/365days of quasi continuous operation of TR30 cyclotrons will be explored.

TH1PB02 09:00 20

Commissioning of the PSI 590 MeV Ringcyclotron for Accepting and Accelerating a Rebunched 72 MeV Proton Beam

***J.M. Humbel** (PSI)*

In the past year the production of a 1.42 MW proton beam at a relative loss level of 10^{-4} at PSI's proton facility became routine operation. In addition, the inaugurated buncher based beam injection into the 590 MeV Ringcyclotron made a remarkable step forward. In particular an almost dispersion free setting of the beamline region around the 500 MHz rebuncher in the 72 MeV transfer line has been established and a perfect matching of the dispersion into the Ringcyclotron has been achieved. This buncher-operation optimized facility setting could be advanced up to the ordinary stable standard 2.2 mA production proton beam - however only at deactivated buncher state. With buncher voltage turned on, the beam extracted from the Ringcyclotron is limited to below 1 mA due to raising losses, mainly generated by space charge induced distortions of the beam bunches. For a better understanding of these effects a substantial effort in modelling of the accelerated beam is under way. In particular the influence of the trim coil fields is being implemented into the OPAL simulation code and the insertion of an additional time structure measurement probe in the Ringcyclotron is proposed.

TH1PB03 09:20 20

Activation Analysis with Charged Particles: Theory, Practice and Potential

***M.A. Chaudhri** (Inst. of Biomaterials, Uni. of Erlangen-Nuernberg)*

Charged particle activation analysis (CPA) is an important application of cyclotrons. It is sensitive and can also activate lighter and other elements, such as Al, Si, Ti, Cd, Tl, Pb, Bi, etc., which cannot be conveniently or at all determined by slow neutron activation (NA). But, the heating of the target in CPA has to be overcome. Besides, it is necessary that the matrices of the sample and the "Standard" are identical or at least similar,which is not always convenient. However, with Chaudhri's method*, CPA is reduced to the simplicity of NA even when matrices of "Standard" and sample are widely different. By using CPA, the effect of French Atomic Tests Series of 1974 in the Pacific on the Australian East Coast was studied. The sensitivity for detecting any element/isotope with Z=20 to Z=90 in any matrix, activated with protons, deuterons and alphas of up to 35 MeV energy have been estimated and presented in graphical form. From these curves the sensitivity of detecting any element/isotope in the aforementioned range can be directly estimated in any given matrix. These curves would help in selecting the most suitable nuclear reaction for the measurement of a particular element.

*A.Chaudhri, N.Chaudhri. Methods of charged-particle activation analysis. Paper presented at the 20th Int. Conf. On Ion Beam Analysis, Itapema (Brazil) 10-15 April, 2011 to be published

TH1PB04
09:40 20

Fabrication of Hydrophobic Surfaces from Hydrophilic BeO by Alpha-Irradiation-Induced Nuclear Transmutation

***E.J. Lee**, M.G. Hur, J.H. Park (KAERI) Y.B. Kong, Y.D. Park, J.M. Son, S.D. Yang (Advanced Radiation Technology Institute, Korea Atomic Energy Research Institute)*

Hydrophobic surfaces were simply fabricated by irradiating hydrophilic BeO surfaces with an alpha particle beam from a cyclotron. In this research, BeO disks were irradiated under conditions of ~25 MeV in alpha particle energy and ~1 μA in beam current with different irradiation time. After the alpha irradiation, the changes in the morphology and chemical composition of BeO surfaces were analyzed using a field emission scanning electron microscopy (FESEM) and X-ray photoelectron spectroscopy (XPS). The wetting property of alpha-irradiated BeO surfaces is analyzed by measuring water contact angles (CAs). C and F atoms were created, and consequently, hydrophobic CFx functional groups were formed by the alpha irradiation of hydrophilic BeO. The amount of CFx functional groups on the surface increases as the irradiation time increases. In addition, the surface roughening, which also affects the surface wettability, was induced by the alpha irradiation. Accordingly, the CA of alpha-irradiated BeO surfaces gradually increases as the irradiation time increases. In conclusion, hydrophilic BeO surfaces could be easily converted to hydrophobic surfaces by the alpha irradiation.

TH2PB — Medical Applications

Chair: J.L. Conradie (iThemba LABS)

TH2PB01 10:30 30

Design of Ultra-Light Superconducting Proton Cyclotron for Production of Isotopes for Medical Applications

M.K. Dey *(VECC)*

A new design has been explored for a superconducting-coil-based compact cyclotron, which has many practical benefits over conventional superconducting cyclotrons. The iron yoke and poles in conventional superconducting cyclotrons have been avoided in this design. The azimuthally varying field is generated by superconducting sector-coils. The superconducting sector-coils and the circular main-coils have been housed in a single cryostat. It has resulted in an ultra-light 25 MeV proton cyclotron weighing about 2000 kg. Further, the sector coils and the main coils are fed by independent power supplies, which allow flexibility of operation through on-line magnetic field trimming. Here, we present design calculations and the engineering considerations, focused on making the cyclotron ideally suited for the production of radioisotopes for medical applications.

TH2PB02 11:00 20

Parasitic Isotope Production with Cyclotron Beam Generated Neutrons

F.M. Nortier, *E.R. Birnbaum, M.E. Fassbender, K.D. John,* ***F.M. Nortier*** *(LANL)*

Several LINAC and cyclotron facilities worldwide generate high intensity beams with primary beam energies in the range 66 MeV to 200 MeV for isotope production purposes. Many of these beams are almost fully subscribed due to the high demand for isotopes produced via proton induced reactions, leaving little beam time available for production of smaller quantities of research isotopes. Modeling and preliminary experimental measurement of the high power proton beam interaction with targets at the Isotope Production Facility at Los Alamos show a high potential for parasitic small scale production of isotopes utilizing the secondary neutron flux generated around the target. This can also be exploited by modern commercial 70 MeV cyclotrons with total beam currents approaching 1 mA and more.

TH2PB03 11:20 20 **The University of Washington Clinical Cyclotron – a Summary of Current Particles and Energies Used in Therapy, Isotope Production, and Clinical Research**

***E.F. Dorman** (University of Washington Medical Center)*

The University of Washington Clinical Cyclotron (UWCC) is a Scanditronix MC-50 compact cyclotron installed in 1983. The cyclotron has now been in operation for 30 years. The unique nature of the cyclotron is its variable frequency RF system, and dual ion source chimneys; it is also capable to produce other particles and energies. Our facility is now sharing beam time between multiple users: Fast Neutron radiotherapy. Development of a Precision Proton Radiotherapy Platform. In vivo verification of precision proton radiotherapy with positron emission tomography. Routine production of 211-At. Routine production of 117m-Sn. Cyclotron based 99m-Tc production. Cyclotron based 186-Re production. Proton beam extracted into air, demonstrating a visual Bragg peak. Neutron hardness for electronic subsystems. These multiple projects show the uniqueness of our facility and our commitment to therapy, radioisotope research and production, and clinical investigations. Currently Running Protons (H^+) 50.5 MeV/75uA, 50 MeV/5-10pA, 35MeV/ 3-5 pA 16, 18, 24, 28MeV/30uA, Protons (H^2) 6.8 MeV/300nA, Deuterons (D^+) 18, 20, 22, 24 MeV/30uA, Alphas (4He++) 29.0 MeV/50uA, 47.3 MeV/70μA.

TH2PB04 11:40 20 **A Multi-Leaf Faraday Cup Especially for Proton Therapy of Ocular Tumors**

***C.S.G. Kunert**, J. Bundesmann, T. Damerow, A. Denker (HZB) A. Weber (Charite)*

The Helmholtz-Zentrum Berlin (HZB) provides together with the University Hospital Charité in Berlin a treatment of eye tumors with a proton beam. The 68 MeV proton beam is delivered by an isochronous cyclotron as main accelerator. In tumor irradiation treatment the positioning of the radiation field is very important. In eye tumor treatment it is even more important, due to the small and sensitive structures in the eye. Hence, due to the well defined Bragg peak, a proton beam is a good choice to achieve rather small fields of dose delivery. Again, due to the small structures in the eye, one needs to know the proton beam energy and the proton beam range with a high accuracy. One possible solution for a quick and high precision measurement of the range of such proton beams is a Multi-Leaf Faraday Cup (MLFC). This work has the task to develop such a MLFC concerning the special requirements of the eye tumor therapy. In this presentation an overview of the progress of this work will be given, regarding the MLFC principles and issues such as the first technical realization.

FR1PB — Medical, Rare Isotope Facilities, Tribute to Henry Blosser

Chair: A. Denker (HZB)

FR1PB01 08:30 20

Operation Mode of AIC-144 Multipurpose Isochronous Cyclotron for Eye Melanoma Treatment

__G.A. Karamysheva__, I. Amirkhanov, I.N. Kiyan, N.A. Morozov, E. Samsonov (JINR) K. Gugula, J. Sulikowski (IFJ-PAN)

Computational and experimental results concerning acceleration and extraction of the 60-MeV proton beam at AIC-144 cyclotron of the Institute of Nuclear Physics (Kraków, Poland) are considered. A proton beam of the AIC-144 cyclotron is accelerated without large losses in the radial region of 12-62 cm and is extracted from the cyclotron with a pretty good overall efficiency of ~35%. The beam was used for successful treatment of 15 patients in 2011-2012.

FR1PB02 08:50 20

Secondary Particle Dose and RBE Measurements Using High-Energy Proton Beams

__M. Ghergherehchi__, J.-S. Chai, J.-S. Chai (SKKU) H. Afarideh (AUT) D.H. Shin (NCC)

High- and intermediate-energy protons are not able to directly form a track in a CR-39 etch detector (TED). Such detectors, however, can be used for the detection and dosimetry of the beams of these particles through the registration of secondary charged particles with sufficiently high values of linear energy transfer (LET). The studied were realized in a clinical proton beam of the NCC Korea, with primary energy of 72 to 220 MeV (1.1 to 0.4 KeV/ μm). The contribution of the secondary particle dose and the value of RBE both increase with decreasing proton energy. A strong agreement between experimentally obtained results and the predicted total cross sections was verified by the Alice code. Stimulation of the secondary particle dose by the Geant4 code also predicted results in agreement by experimental results. It is clear that higher cross sectional values lead to an increased production of secondary particles. This secondary particle dose is highly important for applications such as radiotherapy, radiobiology, and radiation protection.

FR1PB03 09:10 20 **The Radio Frequency Fragment Separator: A Time-of-Flight Filter for Fast Fragmentation Beams**

***T. Baumann**, D. Bazin, T.N. Ginter, E. Kwan, J. Pereira (NSCL)*

Rare isotope beams produced by fragmentation of fast heavy ion beams are commonly separated using a combination of magnetic rigidity selection (mass to charge ratio) and energy-loss selection (largely dependent on proton number) using magnetic fragment separators. This method offers isotopic selection of the fragment of interest, however, the purity that can be achieved depends on the rigidity of the rare isotope with respect to more abundant fragments. This poses a problem specifically for neutron-deficient isotopes (towards the proton drip line) where much more abundant isotopes closer to stability can not be separated out. A separation by time-of-flight can further suppress such isotonic contaminants. The Radio Frequency Fragment Separator* deflects isotopes based on their phase relative to the cyclotron RF using a transverse electric RF field, effectively separating by time-of-flight. This method is in use for the production of neutron deficient rare isotope beams at NSCL.
*D. Bazin et al., Nucl. Inst. and Meth. A 606 (2009) 314-319

FR1PB04 09:30 20 **GANIL Operation Status and Upgrade of SPIRAL 1**

***O. Kamalou**, O. Bajeat, F. Chautard, P. Delahaye, M. Dubois, P. Jardin, L. Maunoury (GANIL)*

The GANIL facility (Grand Accélérateur National d'Ions Lourds) at Caen produces and accelerates stable ion beams since 1982 for nuclear physics, atomic physics, radiobiology and material irradiation. The exotic beams are produced by the Isotope Separation On-Line method with SPIRAL1 facility. It is running since 2001, producing and post-accelerating radioactive ion beams. The review of the operation from 2001 to 2013 is presented. Because of the physicists demands, the facility will be improved with the project Upgrade SPIRAL1. The goal of the project is to extend the range of post-accelerated exotic beams available. The upgrade of SPIRAL1 is in progress and should be ready by 2015.

FR1PB05 09:50 15 **Tribute to Henry Blosser**

***I.V. Bylinskii** (TRIUMF)*

Tribute to Henry Blosser

20-Sep-13 10:30 – 12:30	Pinnacle Ballroom

FR2PB — Rare Isotope Facilities, Medical Isotopes, Summary

Chair: I.V. Bylinskii (TRIUMF)

FR2PB01 10:30 30

Construction of Rare-RI Ring in RIBF

M. Wakasugi *(RIKEN Nishina Center)*

Construction of the Rare-RI Ring has been started in 2012 at RIKEN RI Beam Factory. This ring is an isochronous storage ring aiming at 1-ppm precision mass measurements for short-lived rare nuclei extremely far from stability line. The beam optics in the ring is defined by simply 24 bending magnets, and half of them are accompanied by ten trim coils to precisely optimize the isochronism of circulating beams. The momentum acceptance, in which the isochronous condition is satisfied within 1-ppm accuracy, is designed to be 1%. Of particular note is the development of the exceptionally-fast response kicker system, which is triggered by the produced RI beam itself to make effective use of extremely rare events. In this paper, we present details of the Rare-RI Ring, the status of the construction, and prospects of the project.

FR2PB02 11:00 30

Cyclotron Production of Tc-99m

K.R. Buckley *(TRIUMF)*

Concern over past and impending shortages of Tc-99m have led to renewed interest in the cyclotron production of Tc-99m - the most used radionuclide in Nuclear Medicine. TRIUMF has led a collaboration to implement the irradiation of Mo-100 solid targets on cyclotrons previously only used for the production of PET radionuclides. The technology and irradiation conditions that are critical parameters affecting the purity of the Tc-99m will be presented.

FR2PB03 11:30 30

Conference Summary

M. Seidel *(PSI)*

Conference Summary

FR2PB04 12:00 30

Closing Remarks

I.V. Bylinskii *(TRIUMF)*

Closing Remarks

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Tabacaru, G. MO2PB03
Takahashi, Y. MOPPT008
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Tamura, H. TUPPT009, TUPSH006
Thuillier, T. **TU1PB02**
Tikhomirov, A. MOPPT021
Tobos, L. WE3PB03
Todd, D.S. **MO2PB02**, TUPPT015, TUPSH016, TU3PB02
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Toups, M. WEPPT026, WEPPT030
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Tsutsui, H. **MO3PB02**

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Wakasugi, M.	**FR2PB01**
Wang, C.	MOPPT014, **TU2PB01**, TUPPT006, TUPPT012, TUPPT026, TUPSH002, TUPSH003
Watazawa, K.	MO3PB02
Watt, R.L.	TU4PB04, WEPPT005
Weber, A.	MOPPT002, TH2PB04
Wei, S.M.	MOPPT014, **TUPSH002**
Wen, L.P.	TUPPT006
Winklehner, D.	WEPPT026, **WE3PB03**
Winslow, L.A.	WEPPT026, WEPPT030
Wolf, C.R.	**WE1PB03**

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Xie, H.D.	TUPPT006
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Yajima, S.	MO3PB02
Yamamoto, H.	TUPPT009
Yang, F.	MOPPT014
Yang, J.J.	TUPSH003, WEPPT029, WEPPT030
Yang, S.D.	TH1PB04
Yao, H.J.	MOPPT014, **TUPPT012**
Yasuda, Y.	TUPPT009, TUPPT016, TUPSH006, TUPSH011
Yeon, Y.H.	TUPPT004, **TUPPT019**, **TUPPT020**, TUPPT028
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Yin, Z.G.	MOPPT014, TUPPT006, TUPPT026
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Yorita, T.	MOPPT005, TUPPT009, **TUPPT016**, TUPSH006, TUPSH011
Yoshida, J.Y.	MO3PB02
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Zafiropoulos, D.	MOPPT031
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