APS DPB

Division of Physics of Beams

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Newsletter 2015

In this issue:

Chair's Report 2

From the Editor 2

Twenty-Fifth Anniversary of the Founding of the DPB 2

APS-DPB Amendments to Bylaws 3

Highlights from IPAC'15 4

50 Years of PAC 4

Teachers' Day at IPAC'15 5

Initiatives on Diversity and Inclusion within the APS Division of Physics of Beams 6

Energy Recovery Linac Development 7

The 56th ICFA Advanced Beam Dynamics Workshop on Energy Recovery Linacs 7

Accelerators for Charged Particle Therapy 8

The ICFA Beam Dynamics Panel 11

The ICFA Panel on Advanced and Novel Accelerators 11

NSLS-II, the New Synchrotron Light Source at BNL 12

FRIB Construction 14

The China CEPC-SPPC Project 15

APS Fellows Nominated by the DPB in 2014 17

Robert R. Wilson, IEEE PAST, and USPAS Awards 2015 18

Summaries by Winners of IPAC'15 Student Poster Awards 19

PAST and APS DPB Doctoral Thesis Awards 2015 20

Guide to Grant/Fellowship Opportunities in the DPB Community 20

APS-DPB Executive Council Members 2015 21

Upcoming Meetings 22

Chair's Report

Stuart Henderson, Argonne National Laboratory

It is my privilege to write the Chair's report in the first DPB newsletter in seven years. After a long hiatus, the DPB has committed to publishing the newsletter again. This is an important statement from the DPB Executive Committee about the importance of communications within our community. I certainly hope that you find this issue informative, interesting and useful. Thanks in particular are due to Sam Posen who has taken on the daunting role of editor-in-chief, with support from long-time editor Ernie Malamud.

A common question that I and other members of the Executive Committee receive is "what does DPB do for me?" Hidden within that question is "why should I spend the money to become a member of DPB?" DPB is very active in supporting its members and the larger accelerator community. It sponsors and makes financial commitments to the IPAC and NAPAC accelerator conferences in North America. DPB provides financial support for child care, the Teacher's Day and the Women in Science and Engineering events at these conferences, in addition to providing travel grants to help defray the cost of attendance for students. DPB also sponsors accelerator-related sessions at the March and April APS meetings.

DPB has an important role in outreach, taking part in the larger APS Congressional Visits Day, making the case for science, and especially accelerator-based science. An important vehicle for outreach activities is the popular DPB brochure, *Accelerators and Beams, Tools of Discovery and Innovation*, presently in its 4th printing. Nearly 30,000 of these brochures have been distributed.

One of the initial goals in the formation of DPB 25 years ago was to encourage scholarly publication within the accelerator field. The DPB supports APS publications, especially Physical Review Special Topics – Accelerators and Beams, as a co-sponsor.

One of the primary roles of a professional society is to provide means to recognize colleagues in the field. On an annual basis, DPB nominates APS Fellows, jointly sponsors the Wilson Prize with DPF and recognizes the Outstanding Doctoral Thesis in Beam Physics.

Finally DPB coordinates within APS as well as within the larger world-wide accelerator community, coordinating activities and issues of common interest with other APS Divisions, with the IEEE, the European Physical Society Accelerator Group, the IPAC Coordinating Committee, and recently with IUPAP.

I hope you will agree that your membership in DPB supports many important activities that enrich our field and our professional lives.

For the last several years DPB membership has been in a precarious position, hovering just above the threshold required to maintain Division status, which is 2.1% of all APS members or 1,063 members. Recently, in another attempt to boost membership an offer was made to members of several other APS Divisions in which the DPB would cover the cost of membership for the first year. This campaign was quite successful, and I'm happy to report that the Division's membership now stands at 1249 members, or 2.47% of all APS members. While this measure has helped to shore up membership in the short-term, the long-term impact remains to be seen. Therefore it is critical for our Division to continue efforts toward increasing membership in order to continue to serve our community in all the valuable ways described above. I encourage each member of DPB to make the case for membership and to encourage your colleagues to join.

Finally I would like to close by reaffirming that the DPB serves its members. Therefore, we want to hear from you about ways that DPB can better serve you, our membership and our community.

From the Editor

Sam Posen, Fermilab

Welcome back to the APS DPB Newsletter. In the past, this important medium has informed our community about DPB governance, events, awards, and major news. It also broadcasts this information to those outside the DPB: prospective members of our community, current members of our community who have not joined the DPB (yet), and to the rest of the APS.

This year, we renew this regular communication, and we are adding new content. In this newsletter, you will find articles on IPAC'15, particle accelerator facilities under recent development, awards, and some special topics. This includes the first in what I hope will be a series of articles on accelerators in industrial applications, an article on diversity in the DPB, and a summary of award applications for DPB researchers at various stages of their career from undergraduate onwards.

I would like to extend a tremendous thanks to our contributing authors, who generated the content of this newsletter. I would also like to thank Ernie Malamud for his great help with this issue as well as the DPB Executive Committee.

Twenty-Fifth Anniversary of the Founding of the DPB

Stan Schriber, DPB Secretary-Treasurer

The Division of Physics of Beams (DPB) within the American Physical Society (APS) had an interesting creation about 13.7×10^9 deciseconds ago. As described below it followed typical growth stages—inflation, a quiet period, successive recognizable events when viewed back in time, interesting 'stars' development and lately in a state where expansion of surrounding events had impacts.

Everything started around 1985 with Mel Month from BNL, who among many things worked on Isabelle, was the 'father' of the USPAS and has written a number of interesting books. The situation at that time was interesting from an accelerator physicist's point of view, including the following issues:

- Was there a recognized voice within APS for the accelerator physics community?
- The 5th USPAS School being organized for 1985 at SLAC

(Continued on page 3)

had no ties to APS.

- The important and very successful PAC conferences were not sponsored by APS.
- Most publications by the accelerator physics community were not in APS journals.
- Many accelerator physicists/engineers were members of IEEE, not as many in APS.

Inflation Period Fluctuations: Mel Month had many talks with high energy, nuclear and materials/atomic physicists. In discussions with W.W. Havens, APS Executive Secretary, it was suggested that a petition to form a topical group on beam physics be submitted to APS with the required minimum 25 signatures. Mel was able to travel on USPAS business, so with a petition in hand he visited many labs.

Afterglow Period: Mel interacted with everyone wherever he went and obtained more than 200 signatures for the petition. Excited and back home he called APS only to find out that the petition had to be approved by the APS Council. So, he decided to attend the PAC'85 conference in Vancouver, BC to get more signatures and to get influential APS members to sign.

Dark Ages Period: Mel interacted with everyone attending PAC'85; during breaks, evenings and whenever someone was in the hotel halls or lobbies, to obtain more support. He talked extensively with Pief Panofsky, Leon Lederman, Burt Richter and Bill Wallenmeyer, convincing them to sign the petition. Now his only concern was that the APS Council might veto the petition, because the response received when submitting the petition was "You never know about a Council Decision". For that reason he called Bob Wilson, APS President at the time, to elicit his support.

Formation of a Topical Group on Physics of Beams (TG-PB) was on the January 1986 Council Agenda with Sid Drell as APS President. Discussions at the Council meeting on the new topical group included concerns regarding the impact of the new group on existing APS units, especially the Division of Particles and Fields, DPF.

First Stars: The TG-PB was approved, becoming official within APS records on Nov. 3, 1986. Within a couple of years, the number of members within the Topical Group reached the "magic" 1000. Shortly after this important event, Martin Blume and Bob Siemann initiated the start of the PRST-AB journal, a free access journal of APS. In 1989, Andy Sessler made a presentation to APS Council, on a proposal to make the TG-PB an APS Division. APS Council voted to upgrade TG-PB to a bon-fide APS Division; the Division of Physics of Beams (DPB) started officially in APS records January 1990. Shortly after this event, negotiations began with IEEE-NPSS and the PAC OC, to have APS-DPB become a co-sponsor of the PAC conference series, and share financial and technical responsibilities for the series. A Memorandum of Agreement (MoU) between IEEE-NPSS, PAC OC and APS-DPB was signed May 1993 with Richard Wertheimer signing for APS, Hermann Grunder signing for APS-DPB, O. Nacioglu signing for IEEE-NPSS and Christoph Leemann signing for PAC OC.

Expansion and Dark Stuff: With encouragement from APS-DPB, USPAS continued to develop strongly. Numerous text books on accelerator science and technology were published based on courses taught at USPAS. Other examples of important community information include "Handbook of Accelerator Physics and Engineering", "Reviews of Accelerator Science and Technology (RAST)", "Accelerators and Beams, Tools of Discovery and Innovation" – also known as the Accelerator Brochure, "Engines of Discovery: A Century of Particle Accelerators" and the DOE website http://www.acceleratorsamerica.org "Accelerators for America's Future".

DPB membership remained relatively constant over the past five years – at about 1,125 ± 25. But, the universe was expanding! Over the past several years with a large growth in APS membership especially from students, DPB was in the sad state of potentially losing its status as a Division. With active participation and assistance of APS Membership and other APS Units over the past several months, DPB membership is now about 1,250 and this sad state is no longer a concern.

APS-DPB Amendments to Bylaws

Stan Schriber, DPB Secretary-Treasurer

The Division of Physics of Beams (DPB) within the American Physical Society (APS) can make amendments to their Bylaws by following the procedure listed below. A proposal of an amendment to the APS-DPB Bylaws may be made by the APS Council, by the APS-DPB Executive Committee (EC), or by a petition signed by not fewer than ten percent of the members of the Division.

A proposed amendment from the DPB EC is forwarded to the APS Committee on Constitution and Bylaws (CCB) for their consideration, and iteration with the DPB EC if required. Once there is agreement, the CCB passes their recommendation for adoption to the APS Council. The APS Council reviews the proposed amendment at one of their meetings and if approved, passes it back to the DPB EC for further action. Following Council approval the Secretary-Treasurer distributes copies of the proposed amendment to all members of the Division not less than three weeks before the yearly DPB Business Meeting where the proposed amendment will be discussed. If the proposed amendment is approved by a 2/3 majority vote of those at the Business Meeting, it is sent back to the APS Council with a note specifying that membership has approved the proposed amendment. The Council at their next meeting reviews the proposed amendment again and if approved it becomes an official amendment that is entered within the appropriate records of APS and APS-DPB.

Another method for obtaining membership approval for the proposed amendment to the Bylaws is by using the APS election process. Copies of the proposed amendment are sent to all members of the Division, accompanied by ballot forms for a membership vote during the next APS election process with at least three weeks of open voting allowed. Again adoption of the proposed amendment requires a 2/3 vote in favor.

The latter process was the one used for membership approval of the latest APS-DPB Bylaws amendment involving changes to the Chair line duties, adding a student Member-at-Large and changing the term of office for the secretary-treasurer position.

Highlights from IPAC'15

Andrew Hutton, Jefferson Lab (Conference Chair)

The 6th International Particle Accelerator Conference, IPAC'15, was held May 3-8, 2015 in Richmond, Virginia, sponsored by APS-DPB and IEEE-PAST. The conference attracted 1187 attendees from 309 institutions in 31 different countries, including 458 from the US. There were nearly 100 oral presentations and 1184 posters, an indication of the dynamism of the field of accelerator science and technology.

The conference kicked off with a well-attended student poster session. An international panel evaluated about 100 posters with two winners taking home prizes: Itta Nozawa of ISIR, Japan and Scott Rowan of CERN.

Senator Mark Warner, Virginia who was piped in by the Yorktown Fife and Drum band, opened the conference reception.

The opening session of the conference was devoted to the commissioning results from the 12 GeV upgrade at Jefferson Lab, the higher energy commissioning of the LHC at CERN, extreme UV Lithography with FELs, high Q developments in SRF at Fermilab, and commissioning results from NSLS II at BNL—a broad range of topics that set the tone for the rest of the sessions.

On Wednesday evening, there was a panel discussion of the cultural impact on women in Science and Engineering, with attendance via video by Fabiola Gianotti from CERN where it was midnight, and Haiyan Gao from China where it was 6 am. Prominent women scientists from different backgrounds made up the panel, making this a lively event, particularly for the women students who attended.

The first particle accelerator conference took place in 1965, making 2015 the 50th anniversary. A special session was held to celebrate this event with discussions of the early days of PAC in the USA, EPAC in Europe, and APAC in Asia. These regional conferences joined to create the IPAC series in 2009; so the session closed with a talk on how scientific conferences promote peace.

The conference closed on Friday, but was followed on Saturday with a visit by 150 delegates to Jefferson Lab.

50 Years of PAC

Todd Satogata, Jefferson Lab (JACoW Vice-Chair)

The first Particle Accelerator Conference (PAC) was held 50 years ago, March 10-12 1965, in Washington DC. 745 participants paid a $16 registration fee for the three-day conference, sponsored by IEEE. From its inception, PAC was designed to appeal to both scientists and engineers, and be inclusive to all aspects of accelerator design and operations. PAC'65 had two parallel oral sessions, and published 196 papers in 10 main classifications in a special volume of IEEE TNS. Among the papers in PAC'65 was a paper by L. Smith on "Super-Energy Accelerators" that contained early references to then-unsited designs that would become the 200

(Continued on page 5)

"BeV" Main Ring at FNAL and 300 "BeV" SPS at CERN.

Starting with PAC'71 in Chicago, biennial PACs rotated through eastern, central, and western US conference locations. Registration ranged from 1000 to 1500 from 1985-2010, with peak registration of about 1500 in 1991, concurrent with the advent of large PAC poster sessions to promote thriving discussion. The APS-DPB, soon after its formation, joined IEEE as a co-sponsor of PACs in 1993.

The popularity of PACs led to EPAC (biennial 1988-2008), and APAC (triennial 1998-2007). Organizers of the three conference series met at PAC'07 to form IPAC (annual since 2010), which rotates through the Americas, Europe, and Asia/ Australia. A celebratory session on 50 years of PACs was held at IPAC'15 in Richmond, with speakers on the histories of PAC (Stan Schriber), EPAC (Caterina Biscari), APAC (Shin-Ichi Kurokawa), and Scientific Collaboration Promoting Peace (Hitoshi Murayama). Please see the article on IPAC'15 in this issue.

The long tradition of PAC success now continues with IPACs and a technical NA-PAC conference also held in the Americas every 18 months, coincident with the North American IPAC and interleaved between the other IPACs. Tens of thousands of papers from all 50 years of PAC are available at http://www.jacow.org/. This conference series continues to be the premier conference on accelerator physics and technology, fulfilling the original vision of diversity and inclusion. In 50 years we have seen great progress and growth in our field. Who knows what another 50 years will bring!

1967 PAC Banquet: L. Rosen (third from left), M.S. Livingston (conference chair, fourth from left), L. Teng (fifth from left).

2015 PAC 50th Anniversary Speakers: S. Schriber, S.-I. Kurokawa, C. Biscari, H. Murayama, and A. Hutton (conference chair).

Teachers' Day at IPAC'15

Brita Hampton, Jefferson Lab

On Thursday, 7 May 2015, twenty teachers participated in the 2015 International Particle Accelerator Conference (IPAC'15) Teachers' Day in Richmond, Virginia.

The day began with the teachers attending the Invited Oral sessions. The teachers chose between CEBAF SRF Performance During Initial 12 GeV Commissioning, Innovation and Future of Compact Accelerator Technologies in Medicine and Industry, and Cryogenics and Cryomodules for Large Scale Accelerators, just to name a few! The teachers really appreciated these sessions because, as one teacher said, "I'm normally the smartest one in the room . . . Not today!" Another teacher shared, "I now have a better appreciation for the students who struggle in my class." It was so wonderful to see our teachers embrace this opportunity! The sessions made them think about topics light years beyond where their curriculum ends and it helped them see where their students could be in a matter of years.

After lunch, it was workshop time! The teachers had a workshop on electrostatics and did all sorts of activities exploring positive and negative charges. Each teacher received a "Fun Fly Stick," which is basically a Van de Graaff Generator in wand form. It was so much fun watching the teachers walk around our room trying to keep their mylar strips in the air! The teachers also received a Mini-Theremin. This little instrument makes music courtesy of electrostatic energy. Who doesn't love a little eerie music in the classroom?!

After the electrostatic workshop, Dr. Hitoshi Murayama (from UC Berkeley and Kavli Institute in Japan) kindly shared his story with the teachers. He highlighted some of the teachers that inspired him and encouraged our teachers to keep up the great work. He urged the teachers to encourage students to be curious about things around them, and to think on their own rather than provide answers right away. Dr. Murayama stressed the importance of inspiring students by providing fascinating books, videos, stories, etc. And he ended with encouraging the teachers to talk about what is not

(Continued on page 6)

yet understood . . . That is how we get kids excited!

After Dr. Murayama's talk, it was time for a little competition! The teachers were put into small groups and challenged to build a roller coaster (out of foam pipe insulation) that had all sorts of loops, drops, horizontal turns, etc. etc. A marble would have to travel the length of the roller coaster and not fall out or off. As you can imagine, the teachers had a blast building their roller coasters and the judging was nail biting! This is what teachers live for! Once the competition was over, we seamlessly moved into the next workshop . . . Paper Roller Coasters! There were plenty of pre-made components so the teachers were able to experiment with making their own paper roller coaster. Each teacher was given a class set of paper roller coaster templates so they could get right into using the idea in class the next day.

IPAC'15 Teachers' Day was a success on so many levels! The teachers were exposed to the latest and greatest ideas in particle accelerator physics and walked away with ideas and supplies they could use in their classrooms.

Initiatives on Diversity and Inclusion within the APS Division of Physics of Beams

Camille M. Ginsburg, Fermi National Accelerator Laboratory

The broad field of accelerator physics and technology offers great opportunities for a fulfilling career, yet many capable and interested people do not enter or do not stay in the field. [1] The APS Division of Physics of Beams membership consists of 8% women, and a much smaller fraction of underrepresented minorities (African Americans, Native Americans, and Hispanic Americans) [2]. To advance our field, we must continue to attract and retain the best students and provide them ample opportunity to work on our most interesting problems, and we must be intentional in our strategies to attract and retain diverse talent. The APS has long been committed to equal professional opportunity, without regard to gender, race, national origin, age, religion, marital status, political views, sexual orientation, or disability [3].

To re-confirm the DPB's commitment to equal opportunity, the DPB Executive Committee passed a resolution at our last meeting on May 3, 2015 to establish and support communication with the APS Education and Diversity office. We will accomplish this through the existing DPB Committee on Education and Outreach, by including a diversity component to the committee charge. The updated charge is under review in the Executive Committee.

We can all take concrete steps to share the beauty of accelerator physics and technology with our daughters and their classmates, and to communicate that they are welcome in our field. While our current lack of diversity in the field is a highly complex issue, without any easy solutions, we can personally make significant contributions toward developing an inclusive climate, providing effective mentoring, and addressing implicit bias.

The APS provides a number of tools and recommendations, based on research and broad experience, for improving diversity and inclusion. A webpage on Best Practices for Recruiting and Retaining Women in Physics [4] is focused on women in a university setting, but is broadly applicable to improving the climate for anyone who may feel isolated, or misaligned with the norm, at work.

Mentoring is broadly understood to be a key component of increasing diversity and improving a climate of inclusion at institutions, yet most of us have no training in mentorship. The APS webpages contain guidance and training in mentorship, e.g., through the Physics Research Mentor Training Seminar [5].

The prevalence of implicit bias related to gender, race and other factors is a by-product of being human. If you have not yet done so, try an implicit bias test at Project Implicit [6]. The webpages found therein demonstrate quite vividly that we all have unintentional biases to address before making important judgments or decisions. Daniel Kahneman's book Thinking Fast and Slow [7] includes a fascinating description of how we self-confident technical experts make mistakes by extending our well-developed intuitions to situations or events where they are not relevant. Active awareness of implicit bias and thorough investigation into the reasoning behind our judgments will help us to apply our intuition to those predictable areas in which we are experts, disregard irrelevant factors, and reduce the negative impact of our unintended biases.

An important element of developing our talent pool in accelerator physics and technology is to eliminate barriers that keep underrepresented groups from entering or staying in the field. Each of us can take concrete steps to make a difference. We will continue to publicize our DPB diversity and inclusion initiatives as they are developed. Please send us your suggestions.

The author gratefully acknowledges assistance from and useful discussions with Ted Hodapp (APS Director of Education and Diversity), Sandra Charles (Head, Fermilab Diversity Office), Roger Dixon (FNAL Scientist, APS-DPB Member-at-Large), and Sam Posen (FNAL Scientist, APS-DPB Student Member-at-Large).

[1] C. Singh recently described barriers faced by women physicists: http://www.aps.org/publications/apsnews/201504/backpage.cfm

[2] http://www.aps.org/membership/units/statistics.cfm Jan'15

[3] APS policy 94.3 POLICY ON EQUAL PROFESSIONAL OPPORTUNITY (Adopted by Council on April 23, 1994)

[4] http://www.aps.org/programs/women/reports/bestpractices/index.cfm

[5] http://www.aps.org/programs/education/undergrad/faculty/loader.cfm?csModule=security/getfile&PageID=237523

[6] Project Implicit, https://implicit.harvard.edu/implicit/

[7] Daniel Kahneman, "Thinking Fast and Slow," Farrar, Straus and Giroux, Chapter 22 (2011).

Energy Recovery Linac Development

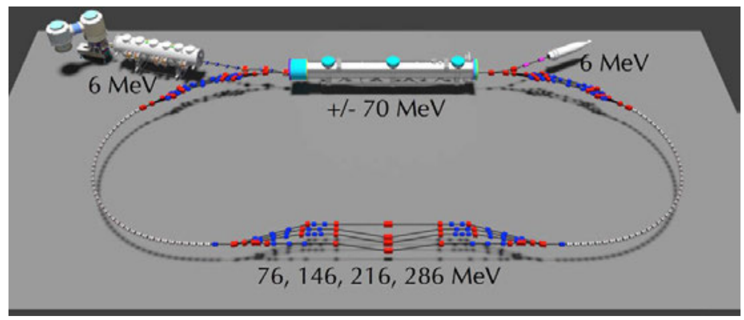
Georg H. Hoffstaetter, Cornell University

ERLs have been proposed for accelerators from rather small industrial applications to large collider experiments, from lithography to hard x-ray sources and from nuclear physics to elementary particle physics. Currently there are active R&D projects for industrial lithography, Compton backscattering X-rays, dark-light searches and other high-current/moderate energy electron-scattering experiments, hard x-ray sources, and electron/ion scattering in eRHIC and LHeC. This breadth of applications and this number of active projects justifies a look at the progress of the ERL field as a whole.

The Energy-Recovery-Linac concept was first suggested in 1965 by Maury Tigner for colliding-beam experiments, during the very early years of SRF cavities, and the 50th anniversary of this invention of ERLs is another good reason for a report in this newsletter. It took 30 years until SRF had developed to the point that the gradient was large enough and the surface losses were small enough to consider Energy Recovery as an option for large-scale accelerators. In the mean time, the ERL principle had been suggested for FELs [2] and had been tested on smaller scales, first at SCA [3] and then for example at the FELs of JLAB, JAEA, and with normal conducting RF in Novosibirsk.

ERL-based hard x-ray sources were proposed by many laboratories and rigorously pursued by Cornell University [4] and KEK. Cornell set out to build a DC photo-emission electron gun and a subsequent injection linac designed for 100mA and normalized emittances of 0.3 mm mrad, to be accelerated in an SRF ERL with an average quality factor of $2x10^{10}$. As of today, 75 mA have been reached, the emittance was measured for individual bunches that correspond to 100 mA and about 0.3 mm mrad were achieved. For smaller bunch charges the emittance was correspondingly smaller. The quality factor has even been pushed to $3x10^{10}$. The beam and accelerator parameters needed to build a diffraction-limited hard x-ray ERL have therefore been achieved. And there is promise to produce an even brighter beam with even better cathodes and an advanced DC gun design. KEK has developed a compact test ERL as a preparation of a 3 GeV ERL-based light source and a 6 GeV XFELO source.

The world's largest ion collider RHIC plans to add an electron beam to collide electrons with ions, and the luminosity is optimal when an ERL is used for this beam. Cavities are currently planned to have 422 MHz, and the ERL has 16 accelerating and 16 decelerating passes. The electron beam of the LHeC collider is similarly produced by an ERL to optimize the luminosity.



The 4-turn FFAG-ERL Cbeta, planned by a Cornell/BNL collaboration. It is to provide 40 mA electrons at 250 MeV.

(Continued on page 8)

The 56th ICFA Advanced Beam Dynamics Workshop on Energy Recovery Linacs, ERL 2015

Sergey Belomestnykh, Brookhaven National Laboratory

The 56th ICFA Advanced Beam Dynamics Workshop on Energy Recovery Linacs (ERL 2015) was held at Stony Brook University, Stony Brook, NY, USA from June 7 to 12, 2015. It was the sixth workshop in the series of international workshops covering accelerator physics and technology of Energy Recovery Linacs.

114 attendees represented institutions from Asia, Europe and USA. 72 talks were presented during plenary and parallel working group sessions. The five working groups (WGs) covered a wide spectrum of topics essential for ERLs. WG1 was dedicated to exploring the results and new technologies available in injectors (lasers, cathodes, guns) since the previous ERL Workshop. WG2 addressed the optics and beam dynamics challenges in ERLs: lessons learnt from past and present ERL operation as well as issues arising during the design work on future ERL facilities. WG3 discussed beam instrumentation, controls, beam losses and halo management. WG4 focused on Superconducting RF technology, RF and RF control to identify the critical issues of each component in cryomodule construction, assembly works and beam operation for ERL. Finally, WG5 reviewed potential applications of the ERL technology, covering a broad range of applications. There was one poster session, where 12 posters have been presented, including a 3D HDTV demonstration of the BNL's eRHIC FFAG accelerator layout and BNL/Cornell Cbeta project. The two plenary sessions at the end of the workshop were devoted to the summary presentations from each working group.

The detail program and talks are available via the workshop website http://www.bnl.gov/erl2015/. The workshop proceedings will be published at JACoW.

Smaller scale ERLs open up a beam-parameter range that has not been utilized experimentally so far. This is the regime of very bright high-current beams with moderate energy of a few hundred MeV. The dark-light experiment that is currently prepared at the JLAB FEL-ERL falls in this regime, and also the planned experiments at the MESA ERL in Mainz, Germany. A workshop was organized at Cornell in June 2015 to look at experiments with these high-brightness, moderate energy ERL beams.

Four small-scale test ERLs are currently in different stages of preparation: the above mentioned compact ERL at KEK will test major concepts of the hard x-ray source but will also be used as a Compton backscattering light source. The Helmholtz Zentrum Berlin has started construction of a 50 mA/50 MeV ERL for accelerator physics, and Cornell is preparing for the construction of a 4-turn ERL with FFAG return arcs, which is shown in the attached figure. This project will prove major concepts of eRHIC and will therefore significantly reduce the risk of this project. At CERN it has been noted that a similar prototyping ERL might be needed in preparation for the LHeC. Cornell's FFAG ERL uses the equipment that has been prototyped, it's DC gun, injector cryomodule (ICM), beam dump, and its main linac cryomodule (MLC). It is to be set up in an existing, well shielded hall that has already been cleared out for this project.

References:
[1] M. Tigner, "A Possible Apparatus for Electron Clashing-Beam Experiments." Nuovo Cimento 37: 1228–1231 (1965).
[2] C. A. Brau, T. J. Boyd, R. K. Cooper, and D. A. Swenson, "High Efficiency Free Electron Laser Systems," International Conference on Lasers, Orlando, Fla., Dec. 17-21, (1979).
[3] T.I. Smith et al., "Development of the SCA/FEL for use in Biomedical and Materials Science Research," NIM A259, 1-7 (1987).
[4] Cornell Energy Recovery Linac, Science Case and Project Definition Design Report, G. H. Hoffstaetter, S. M. Gruner, M. Tigner (eds.), http://www.classe.cornell.edu/Research/ERL/PDDR.html (2013)

Accelerators for Charged Particle Therapy

Jacob Flanz, Massachusetts General Hospital and Harvard Medical School

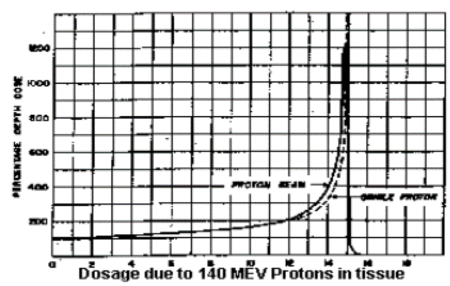
1. Clinically based Requirements

From the time, in 1895 when Roentgen discovered X-rays, and in 1913 when Coolidge developed the vacuum X-ray tube, energetic particles have been an important tool for medicine. Table 1 summarizes some of these applications including the particles used and the energy range required. For use in a medical application, an accelerator must be designed to create a beam which can safely achieve the clinical goals. One such application is radiotherapy. Development of the appropriate tool for effective and safe radiotherapy requires an in depth understanding of the application and constraints. Different technologies can result in different beam properties and these will define how the system can be used to deliver a useful treatment.

Table 1. Medical Applications of Accelerators

Particle	Energy	Application
Electrons	10's keV to MeV	X-Rays
	6 to 25 MeV	Electron/Photon Therapy
	2 to 10 MeV	Sterilization,Food Preservation
	100's of MeV – GeV	Angiography
Protons	10's MeV	Neutron Production/
	10 to 100MeV	Radioisotope Production
	10's-250MeV	Proton Radiotherapy
	500-700MeV	Meson Radiotherapy
Deuterons	7 to 20 MeV	Radioisotope Production
Heavy Ions	70 to 400+ MeV/n	Heavy Ion Radiotherapy

In 1946, Robert Wilson (founding director of Fermilab), while he was at Harvard wrote a paper noting that the 'depth-dose' curve of protons has a finite residual range, with a varying Roentgen equivalent dose (r.e.d.). The curve shown in that paper, which we refer to as the "Bragg Peak" is shown below.



'Depth-dose' curve for a proton beam showing a "Bragg Peak." From a paper by Robert Wilson.

The beam extracted from the accelerator passes through additional systems which may modify the beam properties. Of particular import is the beam delivery system which shapes the beam in 4 dimensions (including time) to conform to the target volume. At the highest level, the goals of radiotherapy are to:

- Deliver the required dose
- Deliver that dose with the prescribed dose distribution, and
- Deliver that dose in the right place

Clinical beam parameters, such as Dose, Dose rate, Range, Distal Falloff, Penumbra and degree of Dose Conformity, among others, will be associated with physical beam parameters such as Beam Current, Beam Energy, Beam shape and size and Beam Position although it is not always a one-to-one correspondence. The requirements may arise from pure clinical treatment parameters to ideas such as using charged particle beam imaging techniques. In addition the treatment parameters can be complicated by the effects of target motion (such as resulting from breathing or heart motion).

Charged particle therapy started over 60 years ago at Berkeley. At first it could only be done in national laboratories. Then in the 1990's the era of hospital-based systems began with Loma Linda aided by FNAL, soon

(Continued on page 9)

followed by industrialization of systems the first of which was installed by IBA at MGH in Boston. We are now in the 3rd generation of systems with advanced features.

2. Accelerator Technology

Accelerators are devices which produce and shape an electric field in such a way as to accelerate the charged particle. For medical therapy safety, stability and reproducible beam properties are of utmost importance. However, from a practical perspective, size and cost is also an issue, when considering using a system for therapy in a hospital environment. One way to reduce the size of the machine and power required to accelerate charged particles is efficient reuse of the electric field (multi pass acceleration schemes). Therefore circular machines such as a Cyclotrons, Synchrotrons or related devices, at this time, are used for particle therapy in these environments. In general, due to the energy of the particles required for clinical use (for example 250 MeV for Protons and 440 MeV/nucleon for Carbon Ions), these accelerators can be larger than a conventional photon LINAC which generally accelerate up to 20 MeV electrons, but lately that is changing.

There is also the opportunity to combine elements of different types of accelerators in order to achieve a balance among beam performance, cost and size. Effort has been applied in the areas represented in the figure below.

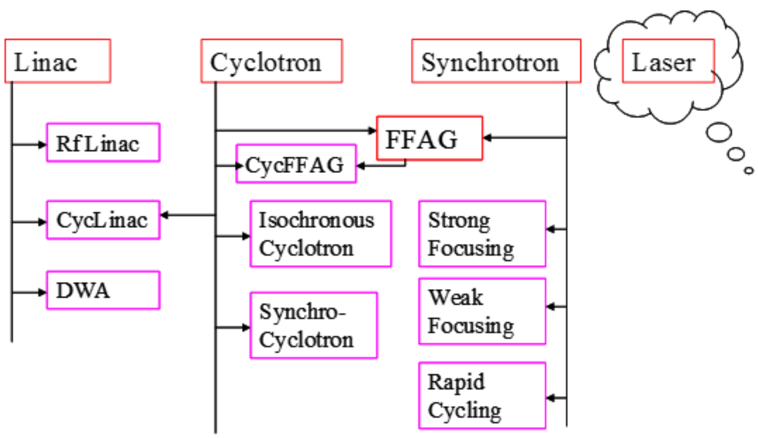
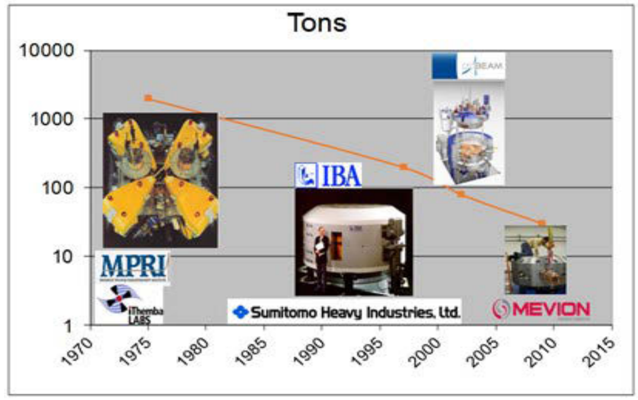


Chart of the types of Accelerators and combinations thereof that are in use or under investigation for charged particle therapy uses.

2.1 Cyclotrons

The size and weight of a cyclotron is primarily determined by the strength of its magnetic field. The radius of curvature of the particle increases as the energy increases. However technology has contributed to the reduction in size and weight as shown in the figure below. One extreme shows the Indiana University cyclotron from the 1970s and the other extreme is the modern superconducting MeVIon cyclotron. Beams extracted from cyclotrons can be either CW or pulsed.



Progress in the reduction of the weight (and cost) of cyclotrons used for Proton Therapy (the weight is expressed in tons).

2.2 Synchrotrons

The size and weight of the synchrotron is primarily determined by the magnet weights also. However since the magnetic field of the magnets increases with increasing particle energy, the volume of the magnets is reduced and the particles travel in a ring.

The first Hitachi synchrotron shown in the figure below (right) is representative of the size of current proton synchrotrons used in medical facilities for proton therapy. The figure to the left is that of the most compact, ProTom synchrotron, but also has the highest energy of 330 MeV protons.

Images of proton therapy synchrotrons. Left: Hitachi original synchrotron; right: ProTom synchrotron.

A significant advancement in the operation of the synchrotron was designed in the Hitachi machine and incorporated in other machines. Typically synchrotron operation is cyclic. However it is sometimes useful to synchronize the beam production with the respiration cycle of a patient, particularly in such an accelerator that is not continuous. In this case, the Hitachi Synchrotron allows for an arbitrary start of the acceleration cycle and is capable of an extended extraction sequence.

The synchrotrons used for heavy ion treatments are larger as shown below including the Heidleberg system and the CNAO synchrotron.

More compact designs are underway using superconducting technology.

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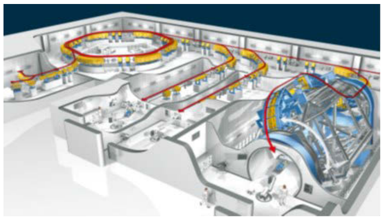
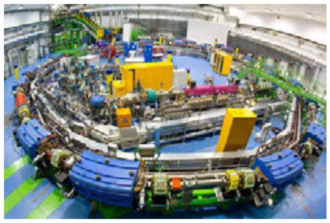


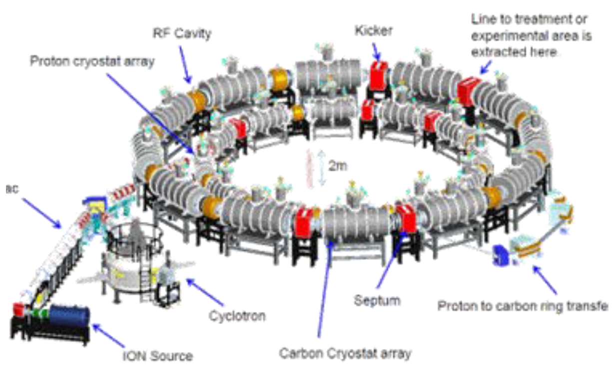


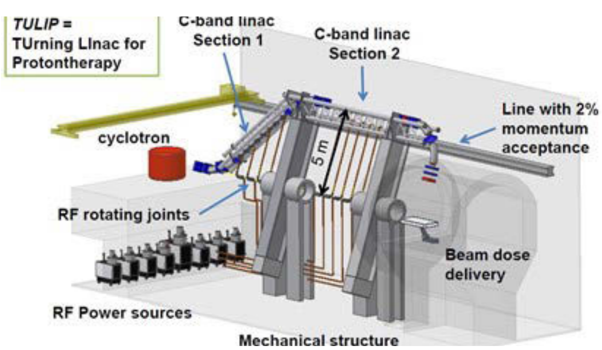
Heavy Ion Synchrotrons. Left: concept drawing of the Heidelberg synchrotron currently in operation; right: photo of the CNAO synchrotron also treating patients now.

3.2 Other Concepts

There are a variety of other concepts including:

- The fixed field alternating gradient (FFAG) accelerator (a concept developed 50 years ago). The figure below of Pamela is an example of a solution for Heavy Ions.
- The CycLINAC which uses a cyclotron as an injector and post-accelerates with fast energy changing capability with a LINAC booster. The image below for Tulip is an example.
- A high gradient Dielectric Wall Accelerator (DWA), and
- Laser accelerator (which may also be useful as an injector device)





Top: Heavy Ion Pamela FFAG concept; bottom: A variant of the Cyc-Linac approach called TULIP (Turning Linac).

Discussion

As one can glean from the variety of accelerator concepts employed and considered, there does not appear to be one clear 'winner', although the cyclotron and synchrotron still predominate. From a high level view, almost all solutions produce the desired beam energy so that's not the issue. However, as one starts to delve deeper into the requirements for treatment the various differences arise. Some of the parameters are inherent in the accelerator physics and engineering, and some are a result of necessary beam modifications external to the accelerator. Clever scientists have found methods to effectively tailor the various beams for use in medical particle beam delivery.

Identification of the constancy or dynamic behavior of the system can help to determine the beam delivery method, and can provide an insight into the complexity of the operation of the system. The time structure of the beam is an important although misunderstood quantity, and some parameters associated with the pulse structure of the various accelerators are important to consider. Finally a relative comparison of the raw emittance (number and shape) extracted from the accelerator could be considered both for the beam delivery design as well as the facility cost. The emittance will in some situations determine the beam size at the target, although devices in the beam path such as ionization chambers, vacuum windows and air will modify that and in some cases make the association between accelerator and clinical values invalid without including additional factors.

The technical equipment consisting of the accelerator, beam lines and gantries must be integrated into a medical facility. This should be done respecting the appropriate requirements of the treatment and context of the environment.

High energy particles have proven useful in medical therapy. Systems have been developed with the necessary safety and parameters. The conformality of the dose distribution with modern scanning techniques are unmatched. The cost effectiveness of such treatments, however are currently in question. Such questions would disappear if the cost and size of these systems were reduced without compromising safety and quality.

References:

[1] Wilson R.R., "Radiological use of fast protons," Radiology, 47 487-491 (1946).
[2] Flanz J. et. al. "Overview of the MGH-Northeast proton therapy center plans and progress," Nucl Instrum Meth in Phys Res B. 99: 830-834 (1995).
[3] Matthews J. *Physics Today*, p22 (March 2009).
[4] Hiramoto K. et. al., "The synchrotron and its related technology for ion beam therapy," Nucl. Instrum. Meth in Phys Rev B. 261: 786-790 (2007).
[5] S. Yamada, et. al., NIRS-M-218 p.170 (2009).
[6] Craddock MK. "The rebirth of the FFAG," CERN Courier 44 (2004).
[7] K. Peach et. al, "Pamela – A model for an FFAG based Hadron Therapy Machine"; THPMN076, Proceedings of PAC07, Albuquerque (2007).
[8] U. Amaldi, et. al., "Cyclinacs: fast-cycling accelerators for hadron therapy," arXiv:0902-3533v1 (2009).
[9] Sampayan S. et. al., "High Gradient Insulator Technology for the Dielectric Wall Accelerator," Proceedings of PAC95, Dallas, Tx, (1995) UCRL-JC-119411.
[10] Faure J. et. al., "A laser-plasma accelerator producing monoenergetic electron beams," Nature, 431:541-544 (2004).
[11] Iwata Y, et al. "Multiple-energy operation with extended flattops at HIMAC," Nucl Instr Method. A624:33 (2010).

The ICFA Beam Dynamics Panel

Weiren Chou, Fermilab and Chair of the ICFA BD Panel

The International Committee for Future Accelerators (ICFA) is a leading body of the world high-energy physics (HEP) community. Although ICFA has no executive power, its decisions have big influence and strong impact on the global HEP program as its members include the leaders of major accelerator laboratories around the world. ICFA has seven panels, each on a specific technical topic. The Beam Dynamics (BD) Panel is one of them. The mission of this panel is "to encourage and promote international collaboration on beam dynamics studies for present and future accelerators." It should be noted that this mission covers not only HEP accelerators, but also accelerators in light sources, neutron sources, FEL, energy, environment, security as well as medical and industrial applications.

The BD panel has 22 members, 3 working groups and 4 regular newsletter correspondents. The panel activities include organizing workshops, meetings, schools and publishing newsletters. There are two types of workshops: the ICFA Advanced Beam Dynamics Workshops (ABDWs) and the ICFA mini-workshops. The former are endorsed by ICFA and require ICFA approval, whereas the latter are endorsed by the BD panel and only needs panel approval. Like other major accelerator conferences and workshops, each ABDW publishes formal proceedings via JACoW. There are several ICFA workshop series taking place on a regular basis: hadron beams (the HB series), future light sources (the FLS series), circular e+e- colliders (the Factories series), energy recovery linacs (the ERL series), etc.

The ICFA Beam Dynamics Newsletter is the only regular publication of ICFA. There are three issues each year: April, August and December. Each issue gives reports on the latest events, announcements and activities in the world accelerator community and also contains a theme section. Panel members take turns to edit. The newsletter is published both online and in print, with a circulation of about 1,300 worldwide including many developing countries. The newsletter articles are not peer reviewed. Nonetheless they are widely referenced in many arXiv and journal publications.

Starting from 2006, the BD panel and the ILC have organized an annual International Accelerator School for Linear Colliders for training young generations of accelerator scientists and engineers for the next big collider after the LHC. The venue rotates among the geographical regions including Japan, Italy, USA, China, Switzerland, India, Turkey and Canada. Many of the early school students are now playing an important or leading role in various accelerator fields.

In view of the importance of laser technology for future accelerators, the BD panel together with the ICUIL (a leading body of the world laser community) and the ICFA Advanced and Novel Accelerators Panel formed an ICFA-ICUIL Joint Task Force in 2010 to promote and encourage international collaboration between the accelerator and laser communities for future applications of lasers for particle acceleration. The task force organized two workshops and published a White

(Continued on page 12)

The ICFA Panel on Advanced and Novel Accelerators

Philippe Piot, Northern Illinois University and Fermilab

Over the recent years the numbers of groups and facilities involved in advanced accelerator R&D (AARD) has been burgeoning worldwide. The AARD landscape has especially evolved due to the increasing availability of high-intensity lasers that have been disseminated in, e.g. small-scale university laboratories, to support research on laser-based acceleration techniques. Likewise, several new facilities available at national laboratories have been dedicated to support AARD or are foreseen to come on line in the next years. Additionally, there have been a rising number of industrial partners interested in AARD to foster the development of small-footprint accelerators for a variety of applications.

Given this evolving landscape, the main mission of the ICFA panel on Advanced and Novel Accelerators (ANA) – to extend and support the international collaboration and communication in the field of new acceleration techniques – is becoming increasingly important.

The ANA panel currently comprises thirteen members and is chaired by Dr. Brigitte Cros. The panel's webpage is accessible from the main ICFA webpage
and is currently located at this link. At least one member serves as local contact for each geographical region (Americas, Asia and Europe).

Over the last year the major activities of the ANA panel has been to establish a new web site, and endorse workshops. The two events endorsed by the ANA panel in 2015 include the laser and plasma accelerator workshop (LPAW15, May 11 -17 2015 Guadeloupe, France) and the 2nd European Advanced Accelerator Concepts Workshop (EAAC15, September 13-20, Isola d'Elba, Italy). A new website was set up and now compiles a tentative list of laboratories, academic institutions and industrial partners actively engaged in advanced-accelerator R&D. The listing includes contacts for the lead investigators and short descriptions of the research being performed and/or of the facility capabilities. This list is by no means exhaustive and we strongly invite participants of the ANA community and others to comment, and especially send corrections or missing information to their respective geographical contacts (see ANA website for e-mails). Additionally, since 2015, our panel has started to record the peer-reviewed publications in advanced accelerator R&D on its webpage. Again to ensure an accurate list, members of the AARD field are encouraged to send their publications to the ANA panel. The intent of these documentations is to provide a comprehensive source of references readily accessible to our community and especially to newcomers (e.g., students) while showcasing the vitality of our field.

Paper with the title "High power laser technology for accelerators." (ICFA Beam Dynamics Newsletter, no. 56, pp. 10-88, December 2011)

In addition to these main activities, the panel also contributes to the deeds of the global science in various ways, e.g., providing information to the OECD upon its request, compiling a world accelerator catalog, supporting the initiative of establishing an annual international particle accelerator conference (IPAC), etc.

The ICFA Beam Dynamics Panel is a panel for everyone working in the accelerator field. We welcome your comments, suggestions and contributions to the panel activities.

NSLS-II, the New Synchrotron Light Source at BNL

Ferdinand Willeke, Brookhaven National Laboratory

Aerial view of NSLS-II, the New Synchrotron Light Source at BNL

An era came to an end on 30 September 2014, when the National Synchrotron Light Source (NSLS) ended its last run after more than 30 years of operation at BNL. NSLS was the first of the modern synchrotron light sources and had an enormous impact on synchrotron-light-based science over the past decades. It contributed a wealth of pioneering scientific results, including work that resulted in two Nobel prizes. The following day, 1 October, a new era began for Brookhaven, with the startup of the new facility, NSLS-II, which is designed to provide the brightest beams ever produced by a synchrotron light source.

The mission for a follow-up to NSLS which was acknowledged by DOE was to provide a factor of 10 more flux (number of photons per second) and up to four orders of magnitude more brightness (spectral flux density) relative to the earlier machine. It was to be capable of achieving energy resolution of a fraction of a milli-electron-volt and spatial resolution on the nanometer scale. The new light source was to enable novel science opportunities in all fields of synchrotron-radiation-based science and would allow experiments that were not possible at any of the other facilities at that time. The project went swiftly through the design and R&D phase with critical decisions CD-1 and CD-2, and in June 2009, CD-3 was approved, allowing construction of the facility to begin.

The NSLS-II electron storage ring consists of 30 double-bend achromates (DBA) separated by 15 long (9.3 m) and 15 short (6.6 m) straight sections for insertion devices, which are the source of ultra-bright synchrotron radiation. The straight sections contain the undulator and wiggler magnets which produce the ultra bright synchrotron radiation. The ring is operated at 3 GeV beam energy. In order to achieve the desired high brightness based on a horizontal beam-emittance of $\varepsilon_x = 0.8\ \pi$ nrad m, it has a large circumference of 792 m and strong wiggler magnets to increase radiation damping.

NSLS-II has high field quality electromagnets for bending, focusing and nonlinear corrections of the beam. The alignment of the magnetic centres with respect to each other is held to unprecedentedly small tolerances with rms values of less than 10 µm, which was achieved by a novel stretched wire based method.

The other critical parameter for high-brightness performance is the beam current of 500 mA. High beam current is obtained with an accelerating structure based on two single-cell 500 MHz superconducting cavities of the type known as CESR-B.

View of the NSLS-II Accelerator Tunnel

Beyond-state-of-the-art instrumentation is required to control the orbital stability of the beam with its small beam sizes (σ_y = 3 µm at the insertion devices). Therefore, both a novel beam-

(Continued on page 13)

position monitor system with a resolution and stability of less than 200 nm and a fast orbit-feedback system have been designed and implemented to suppress beam motion induced by vibrations of the magnet support system. These will limit motion of the beam orbit to within 30 nm for frequencies up to 1 kHz.

The vacuum system is made of extruded, key-hole shaped aluminium. The antechamber houses two non-evaporable-getter (NEG) strips for distributed pumping. The girder system is designed for high thermal stability and to avoid amplification of mechanical vibrations below 30 Hz.

All of the electronics and power supplies are located on the roof of the accelerator tunnel and are housed in sealed air-cooled racks. In this way, the sensitive equipment is protected from dust, temperature fluctuations, humidity and leaking cooling water. This protection is a major element of the strategy to achieve high operational reliability for the more than 1000 magnet power supplies, the beam-position monitors, controls and vacuum-control equipment. The facility aims for a reliability (uptime) greater than 95% once its operation is fully matured.

The NSLS-II injector consists of a 200 MeV S-band linac, which feeds the 3 GeV combined-function booster synchrotron for on-energy injection in "top-off" mode, where frequent injection maintains the storage ring beam current. The booster synchrotron was designed and built by the Budker Institute of Nuclear Physics in Novosibirsk and installed in collaboration with NSLS-II staff.

The civil construction with the accelerator tunnels and the ring-shaped experimental floor was completed in 2012. Installation of the accelerator components, which started in 2011, was completed in 2013.

NSLS-II injector commissioning started in November 2013 and Storage-ring commissioning took place soon after, in April 2014. The commissioning time for the entire complex was remarkably short, the superb robustness and reproducibility of the machine being demonstrated by the fact that restarts are possible only a few hours after shut downs.

The summer of 2014 saw the installation of the first NSLS-II insertion devices. Three pairs of 3.4 m long damping wigglers with a peak field of 1.85 T not only provide a factor of two in emittance-reduction by enhanced radiation-damping, they are also powerful sources (195 kW at a beam current of 500 mA) of photons up to energies of 100 keV. The workhorses of NSLS-II are in-vacuum undulators with a period of 20-23 mm and an extremely small gap height of 5 mm. Four such devices of up to 3 m in length are part of the initial installation plan. There is also a pair of 2 m long elliptical polarizing-undulators (EPUs). The insertion devices were commissioned with their corresponding front-end systems during autumn 2014.

An initial suite of six beam lines is also part of scope of the NSLS-II project. These beam lines are based on state-of-the-art – or beyond – beam-line technology. They cover a range of synchrotron-light experimental techniques, including powder diffraction (XPD), coherent hard X-ray scattering (CHX), nano-focus imaging (HNX), inelastic X-ray scattering with extreme energy resolution < 1 meV (IXS), X-ray spectroscopy (SRX) and coherent soft X-ray scattering (CSX). All of these beam lines have started technical commissioning. The very first light emitted by the NSLS-II EPU was observed on 23 October in the CSX beam line, followed by similar events for the other beam lines.

At the same time as the science commissioning of the existing beam lines at NSLSI-II is taking place, nine further insertion-device beam lines are under construction. The first three, known as the ABBIX beam lines, are scheduled to start up in the spring of 2016. They are specialized for biological research. The other six insertion-device beam lines – the so-called "NEXT" beam lines – are planned to start up the following autumn. Finally, there is an ongoing program that consists of reusing NSLS equipment and integrating it in five new beam-lines (NxtGen) that will receive bending-magnet radiation. As the field of NSLS-II dipole magnets is weak, some of the source points are equipped with a wavelength-shifter consisting of a three-pole wiggler with 1.2 T peak field.

In addition, a number of external institutions have responded positively to the opportunity to work with NSLS-II and they will develop five additional beam lines in collaboration with NSLS-II staff. Thus by 2018, NSLS-II will run with 27 beam lines and will have recovered from the reduction in the scientific program between the shutdown of NSLS and the development period of the NSLS-II user-facility. In its final configuration, the NSLS-II facility will host more than 60 beam lines. The bright future of the NSLS-II era has begun.

NSLS II was constructed under DOE contract No. DE-AC02-98CH10886.

FRIB Construction

Jie Wei , Michigan State University

In August 2014, the Department of Energy's Office of Science approved Critical Decision-3b (CD-3b), Approve Start of Technical Construction, one year after approving CD-2 (Approve Performance Baseline) and CD-3a (Approve Start of Civil Construction and Long Lead Procurements) for the FRIB construction project (Fig. 1). The total project cost for FRIB is $730M, of which $635.5M is provided by DOE and $94.5M is provided by Michigan State University (MSU). The project will be completed by 2022. "When completed, FRIB will provide access to completely uncharted territory at the limits of nuclear stability, revolutionizing our understanding of the structure of nuclei as well as the origin of the elements and related astrophysical processes." [1]

The Facility for Rare Isotope Beams (FRIB) will be a new national user facility for nuclear science. Under construction on campus and operated by MSU, FRIB will provide intense beams of rare isotopes (that is, short-lived nuclei not normally found on Earth). FRIB will enable scientists to make discoveries about the properties of these rare isotopes in order to better understand the physics of nuclei, nuclear astrophysics, fundamental interactions, and applications for society.

In creating this new one-of-a-kind facility, FRIB builds upon the expertise and achievements of the National Superconducting Cyclotron Laboratory (NSCL), a National Science Foundation (NSF) user facility at MSU. Since 2001, NSCL's coupled cyclotron facility, one of the world's most powerful rare isotope user facilities, has been conducting experiments on rare isotopes. Since 2014, the re-accelerator (ReA3) consisting of a radio-frequency linac (RFQ) and superconducting radio-frequency (SRF) linac was constructed and commissioned accelerating beams of rare isotopes. The FRIB project scope consists of a high-power driver accelerator, a high-power target, and fragment separators. The FRIB driver accelerator is designed to accelerate all stable ions to energies > 200 MeV/u with beam power on the target up to 400 kW. The driver accelerator consists of electron-cyclotron-resonance (ECR) ion sources; a low energy beam transport containing a pre-buncher and electrostatic deflectors for machine protection; a radiofrequency quadrupole (RFQ) linac; linac segment 1 (with quarter-wave-resonators (QWR) of β_0=0.041 and 0.085) accelerating the beam up to 20 MeV/u where the beam is stripped to higher charge states; linac segments 2 and 3 (with half-wave-resonators (HWR) of β_0=0.29 and 0.53) accelerating the beam > 200 MeV/u; folding segments to confine the footprint and facilitate beam collimation; and a beam delivery system to transport to the target.

Site of FRIB civil construction. Construction of the underground accelerator tunnel is completed.

FRIB accelerator systems design and construction have been facilitated under work-for-others agreements by many DOE-SC national laboratories including ANL, BNL, FNAL, JLab, LANL, LBNL, ORNL, and SLAC, and in collaboration with institutes worldwide including BINP, KEK, IHEP, IMP, INFN, INR, RIKEN, TRIUMF, and Tsinghua University. The cryogenics system is developed in collaboration with the JLab cryogenics team. The recent experience gained from the JLab 12 GeV cryogenic system design is utilized for both the refrigerator cold box and the compression system designs. The charge stripping system is developed in collaboration with ANL. Tests with a proton beam produced by the LANL LEDA source were conducted demonstrating that power depositions similar to the FRIB uranium beams could be achieved without destroying the liquid film. BNL collaborated on the development of the alternative helium gas stripper. The SRF development benefited greatly from the expertise of the low-β SRF community. FRIB is collaborating with ANL on the coupler and tuner developments, assisted by JLab for cryomodule design, and by FNAL and JLab on cavity treatments. FRIB is collaborating with LBNL on the development of VINUS-type ECR ion source.

Major accelerator R&D and subsystem prototyping have been completed. The figure below shows the recent test of the FRIB prototype β_0=0.085 cryomodule developed at MSU together with the FRIB prototype cryogenic distribution line developed by JLab.

Test bunker containing the FRIB prototype β_0=0.085 cryomodule and the prototype cryogenic distribution line.

About 65% of baselined major procurement funds have been either spent or committed. Both domestic and foreign industrial providers are engaged based on best-value practices. Intense vendor coordination ensures timely execution of contracts.

High availability, maintainability, reliability, tunability and upgradeability are essential ingredients of the design philosophy for the accelerator to operate as a science user facility.
The project will be completed by June 2022. Early completion is targeted for December 2020 to reach the key performance parameters.

References:
[1] DOE Statement August 5, 2013 http://www.frib.msu.edu/content/doe-office-science-approves-cd-2-and-cd-3a .

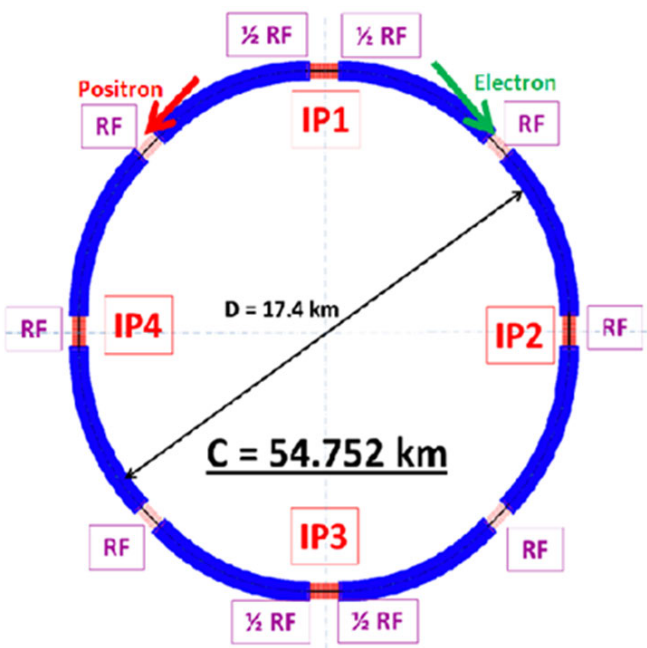
The China CEPC-SPPC Project

Circular Electron-Positron Collider — Super Proton-Proton Collider

Ernie Malamud, Fermilab Scientist Emeritus

Over the past half year I have participated in the development of a preliminary Conceptual Design Report (pre-CDR) for the ambitious Circular Electron-Positron Collider – Super Proton-Proton Collider (CEPC-SPPC) project. [1, 2] My role was to smooth out the English, but I was also able to contribute to the content by drawing on many years of accelerator experience and participation in the preparation years ago of a similar large report. [3]. I spent two weeks at the Institute for High Energy Physics (IHEP) in December and two more weeks this past March.

The pre-CDR was been authored by 299 authors from 57 institutions in 9 countries. The study was led by IHEP and completed in time to be presented at FCC week in Washington. [4]. It is impressive how this group, mostly young hard-working Chinese physicists and engineers, developed the CEPC-SPPC project in less than a year.



Proposed layout of the CEPC. The main collider is 8-fold symmetric, and has 8 arc sections and 8 long straight sections.

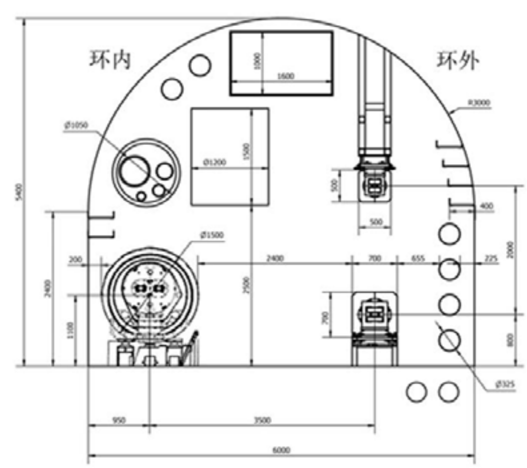
The discovery of the Higgs at the relatively low mass of 126 GeV revived interest in large-circumference circular colliders. And with a large circumference tunnel, it also revives our dream of a super high-energy hadron collider, a dream that died with the demise of the SSC.

The pre-CDR concentrates on the accelerator physics and the technical systems required to achieve the performance goals of the e^+e^- Higgs factory. The pp machine is not yet developed in detail. An important feature of CEPC-SPPC is the tunnel is large enough for a pp ring without disturbing the lepton collider; both physics programs could be run simultaneously, and there is the exciting future option of ep and eA collisions.

Four straight sections, about 1 km each, are for the interaction regions and RF. IP1 and IP2 are for the CEPC and IP3 and IP4 are reserved for the SPPC. Another four straight sections, about 850 m each, are for RF, injection and beam dump. Injection into the lepton main ring is shown. The lengths of these straight sections are determined by taking into account the future needs of the huge detectors and complex collimation systems of the SPPC. The total length of the straight sections is about 14% of the ring circumference, similar to the LHC.

The tunnel will be 50 - 100 m below ground, to accommodate these three ring accelerators: the CEPC collider, the SPPC collider, and a full energy CEPC booster. While the two colliders will be mounted on the floor, the booster will hang from the ceiling, similar to the Recycler in the Main Injector tunnel at Fermilab.

Although most of the detailed work in the pre-CDR assumes C=54.7 km. the option is open for an increased circumference ring. The e^+e^- working parameters are cm energy 240 GeV and integrated luminosity per IP per year of 250 fb^{-1}. Higgs bosons are produced mainly through the $e^+e^- \rightarrow ZH$ reaction. At CEPC the Higgs can be detected through the recoil mass method by reconstructing only the Z without including the recoiling H. Therefore, Higgs production can be disentangled from its decay in a model independent way. Moreover, the environment at a lepton collider allows clean exclusive measurement of Higgs decay channels. The CEPC will have an impressive reach in probing Higgs properties. With an integrated luminosity of 5 ab^{-1}, over one million Higgs will be produced. Also of significant interest will be high-luminosity runs at the Z-pole, 45 GeV per beam.



Tentative layout for the 6-m-wide tunnel. On the right hanging from the ceiling is the full circumference CEPC booster and below it is the 240 GeV (cm) e^+e^- collider. On the left is sketched a possible pp collider with two aperture magnets. There is sufficient space between the two accelerator systems for service vehicles.

(Continued on page 16)

Important decisions for the CEPC were (1) to have a one-ring collider so both electrons and positrons travel in the same beam pipe, and (2) to have a full-energy booster. There are both advantages and disadvantages to these choices. The one-ring collider is similar to BEPC-I, LEP and CESR. An alternative design, which is preferred for beam physics considerations and machine operation, but which costs more, is to use two beam pipes as in BEPC-II, PEP-II, KEKB and DAFNE. Two-beam pipes could give higher luminosity because a larger number of bunches are allowed. With a single ring, one has to cope with the complications of a pretzel scheme. The collider will run in top-up mode.

Injection into the CEPC booster will be from an above ground 6 GeV normal-conducting S-band linac. A major challenge is to achieve adequate magnetic field uniformity at the low injection field of 0.0614 T. One scheme being pursued is a wiggling bend solution that combines magnets whose bends partially cancel each other and together create the desired integrated field. Operating the magnets at higher currents makes for more stable operation.

More than 65% of the booster and main ring circumference will consist of dipole magnets. Therefore, the magnet cost becomes an important issue, especially the dipole magnets. Since the field of the dipole magnets is very low, as in LEP's dipole magnets, steel-concrete cores will be used to reduce costs since concrete substitutes for 75% of the steel. By increasing the magnetic induction in the iron, the magnets are less sensitive to variations in iron quality and in particular to the coercive force.

The top level parameters for the pp collider are less certain. The energy, of course, depends on the final ring circumference and achievable magnetic fields in production magnets. A luminosity goal is 10^{35} but there is considerable debate in the HEP community of what it needs to be for the physics one is aiming at but also the ability of future detectors to handle these high luminosities. Besides the challenges in the detectors, very high synchrotron radiation and very strict beam loss control associated with a high circulating current are major challenges to the vacuum system and the machine protection system.

Center of mass energies will depend on the final choice of circumference and what can be achieved in the magnet R&D program. With the 54.7 km circumference, 70 TeV cm can be realized if the magnets, probably constructed from a combination of Nb_3Sn and high-temperature SC coils can operate at 20 T. This is an optimistic extrapolation to "decades -from-now" technology.

These energies are a factor of 5 to 7 jump from LHC, which itself is a factor of 7 jump from the Tevatron. So this is a logical future step as humanity pushes the energy frontier forward.

For the SPPC a four-stage injector chain has been envisioned: a 1.2 GeV proton linac, a rapid cycling (25 Hz) 10 GeV synchrotron, followed by a 100 GeV, 0.5 Hz machine and finally a 2.1 TeV superconducting injector into the SPPC. Each of these accelerators, when not needed for injection, can support an interesting physics program.

There are numerous possibilities for the site. As was learned from Fermilab and SSC, choosing a site is complex and many factors are involved. In the pre-CDR a candidate site near Qinghuangdao, a city of 2 million, about 300 km east of Beijing, is described. This site has excellent geology, adequate water, and good access. During December I visited this site on a Sunday outing.

After considering the details of the technical systems as well as the civil construction it is possible to make a tentative time line for the CEPC a 5-year R&D phase followed by a 7-year construction period.

CEPC will require two large SRF systems: 384 cavities operating at 650 MHz for the Collider and 256 cavities operating at twice the frequency for the Booster. The CEPC SRF system will be one of the largest and most powerful SRF accelerator installations in the world. To succeed with designing, fabricating, commissioning and installation of such a system, a significant investment in R&D, infrastructure and personnel development is necessary. The RF stations provide 12 GeV of RF voltage. All the cavities will be cooled in a liquid-helium bath at 2 K. Thus the cryogenic system is a major component of CEPC. The majority of the R&D budget (58%) will be invested in the "big three" systems – SRF, RF power source and cryogenics.

Operations cost is also a major issue. It is mainly determined by the power consumption. When the Tevatron was running, the average total power usage was 58 MW. When the LHC was running, CERN used 183 MW (average over 2012). A consensus for operating a future circular Higgs factory is that the power should not exceed 300 MW, in which 100 MW is for synchrotron radiation. In other words, a wall plug efficiency of 1/3.

This clearly is work in progress. Parameters may change but the basic concept is sound.

References:

[1] "CEPC-SPPC, Preliminary Conceptual Design Report,". IHEP-AC-2015-001. A second accompanying volume, IHEP-CEPC-DR-2015-01, is on Physics and Detectors. Both volumes can be downloaded from http://cepc.ihep.ac.cn/preCDR/volume.html.

[2] A preliminary version of this report appeared in the spring 2014 Newsletter of the APS Forum on International Physics. http://www.aps.org/units/fip/newsletters/201502/china.cfm

[3] Design Study for a Staged Very Large Hadron Collider, Fermilab TM-2149, (June 4, 2001).

[4] FCC week. Co-sponsored by CERN and the US Department of Energy Office of Science. http://indico.cern.ch/event/340703/overview

APS Fellows Nominated by the DPB in 2014

Congratulations to the six new APS fellows nominated by the DPB in 2014. Their important contributions to beam physics are briefly summarized here, with images from those able to attend a recognition ceremony at IPAC 2015.

Mei Bai (left) and Stephen Gourlay (right).

Bai, Mei (*Brookhaven National Laboratory*)
Citation: For outstanding contributions to the dynamics of spin-polarized beams and the acceleration of polarized protons for the first high energy polarized proton collider.

Fawley, William M. (*Lawrence Berkeley National Laboratory*)
Citation: For his sustained contributions to beam physics, leading to the successful operation of coherent light source user facilities based on free-electron laser and related concepts and driving developments in intense relativistic electron and heavy-ion beam transport.

Hartemann, Frederic V. (*Lawrence Livermore National Laboratory*)
Citation: For remarkable insights and significant contributions to the physics of coherent radiation interacting with relativistic electrons.

Jowett, John M. (*CERN*)
Citation: For groundbreaking contributions to the design and commissioning of particle colliders, in particular for the mathematical modeling of electron beams in storage rings, for developing an operation scheme with a large number of bunches in LEP, for the design of tau-charm factories, and for the use of the LHC as a lead-lead and proton-lead collider.

Vitaly Yakimenko (left) and Stephen Gourlay (right).

Yakimenko, Vitaly (*SLAC National Accelerator Laboratory*)
Citation: For his pioneering work in the production, characterization and application of high-brightness sub-micron emittance electron beams and the development of advanced accelerator concepts.

Alexander Zlobin (left) and Stephen Gourlay (right).

Zlobin, Alexander V. (*Fermilab*)
Citation: For his multi-year leadership, personal innovative contributions and achievements in the development and demonstration of new generation superconducting accelerator magnets based on Nb_3Sn superconductor.

Robert R. Wilson Prize for Achievement in the Physics of Particle Accelerators, 2015

*Awarded to **Hasan Padamsee***

Citation:
"For his leadership and pioneering world-renowned research in superconducting radiofrequency physics, materials science, and technology, which contributed to remarkable advances in the capability of particle accelerators."

Background:
Prof. Hasan Padamsee received his BS in Physics from Brandeis University in 1967, and his PhD in Physics from Northeastern University, Boston Mass in 1973. Since then he worked at Cornell University in Superconducting Radio Frequency (SRF) science and technology for application to a wide variety of Particle Accelerators. His scientific contributions to SRF include understanding the nature of thermal breakdown and curing it by using high Resistivity Ratio, pure Niobium. In 1981 he was a visiting scientist at CERN. At Cornell he launched in 1990 the TeV Energy Superconducting Linear Accelerator (TESLA) which morphed into the TESLA collaboration headed by DESY, and subsequently into the International Linear Collider (ILC). After teaching SRF courses extensively at the USPAS and CERN Accelerator Schools, he authored two widely used text books in SRF published by Wiley. Padamsee received the IEEE Particle Accelerator and Science Technology (PAST) Award in 2012. He was elected APS Fellow in 1993. He mentored many graduate students over the course of his career. In 2014 Fermilab appointed Padamsee as Head of the Technical Division to oversee the development of SRF for the Linac Coherent Light Source –II at SLAC, as well as for Proton Improvement Program (PIP-II) at Fermilab.

IEEE Particle Accelerator Science and Technology (PAST) Technical Committee Awards, 2015

*Awarded to **Sergey Belomestnykh***

Citation:
"For achievements in the science and technology of RF and SRF for particle accelerators."

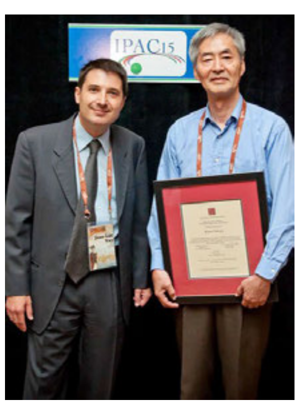
*Awarded to **Ivan Bazarov***

Citation:
"For contributions to science and technology of energy recovery linacs and high-brightness photoinjectors."

USPAS Prize for Achievement in Accelerator Physics and Technology, 2015

*Awarded to **Kaoru Yokoya***

Citation:
"For his numerous fundamental and wide ranging contributions to accelerator physics, including the understanding and modeling of the beam-beam interaction, polarization in storage rings, beam instabilities, accelerator impedance, coherent synchrotron radiation, and novel accelerator concepts."



Jean-Luc Vay (left) and Kaoru Yokoya (right).

*Awarded to **Rami Kishek***

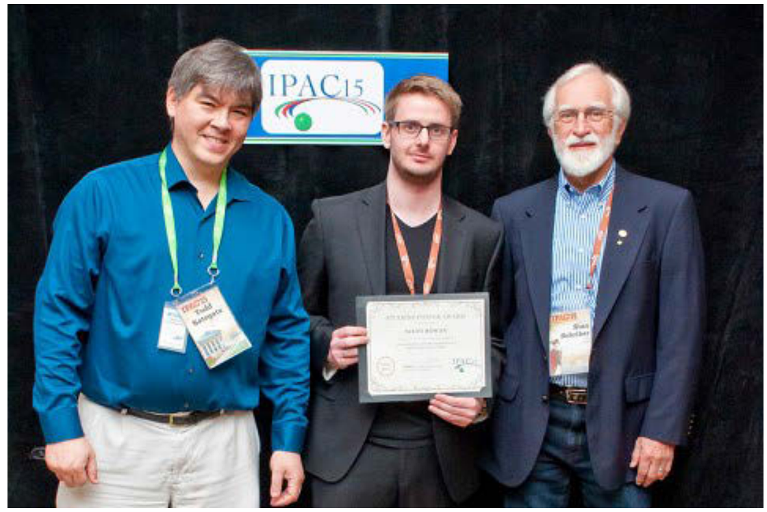
Citation:
"For groundbreaking work on the theory of multipactor discharge, his contributions to the understanding of physics of space-charge-dominated beams and his excellent mentorship of young scientists."

Jean-Luc Vay (left) and Rami Kishek (right).

Summaries by Winners of IPAC'15 Student Poster Awards

Congratulations to the two winners of the Student Poster Awards at IPAC 2015, Itta Nozawa and Scott Rowan! Below are summaries that the students have written for the general community describing their work.

From left to right: Todd Satogata, Itta Nozawa, and Stan Schriber.



From left to right: Todd Satogata, Scott Rowan , and Stan Schriber.

Bunch Length Measurement of Femtosecond Electron Beam by Monitoring Coherent Transition Radiation

Itta Nozawa, ISIR, Japan

Our laboratory aims to investigate ultrafast phenomena induced by ionizing radiation in an extremely short time. Pulse radiolysis, one of the time-resolved methods, is used to elucidate the phenomena, and the time resolution of the pulse radiolysis system strongly depends on bunch lengths of electron bunches. Thus, in order to improve the time resolution, I studied the generation of femtosecond electron beams using an S-band laser photocathode RF gun linac at Osaka University, and I carried out bunch length measurement of the femtosecond electron bunches. When an electron bunch emits radiation, the radiated electromagnetic waves become coherent at wavelengths longer than the bunch length. In other words, the spectrum of the coherent radiation contains information of the bunch length of the electron bunch. My study is based on this idea of coherent radiation. I monitored coherent transition radiation using a Michelson interferometer, and the electron bunch lengths were estimated by fitting an analytical function to experimentally obtained interferograms of coherent transition radiation. In the present experiment, electron bunches with pulse durations of several femtoseconds were observed using the method described above. In the future, I would like to improve the accuracy of this method and contribute to generation and characterization of ultrashort electron beams with sub-femtosecond pulse durations.

Interactions between Macroparticles and High-Energy Proton Beams

Scott Rowan, CERN

'Run 2' will see the LHC operate with 6.5 TeV beam energy, up from 4 TeV. To acheive this, the main superconducting dipoles were quench trained, but due to time constraints, only with minimal margins. This increases the probability of scattering due to dust/macroparticle-to-beam interactions resulting in a magnet quench, threatening LHC availability. As a result, beam-loss monitor (BLM) thresholds have to be optimized to maximize beam lifetime, but prevent magnet quenches. The LHC is the first proton machine where this phenomenon has become problematic.

A numerical model was developed to simulate macroparticle-to-beam interactions in which a dust particle falls into the beam, becomes ionized and is subsequently repelled. Furthermore, the model calculates the beam losses and probability of a magnet quench. The constructed model was capable of accurately simulating BLM signals of events measured during 4 TeV operation. Following this, Monte-Carlo simulations were carried out and, using realistic distributions for macroparticle size and location, one could similarly reproduce the 2012 recorded data set of over 1800 events.

Extrapolating to 6.5 TeV, dipole quench level uncertainties varied predictions of such an event resulting in a quench by a factor of 10, between 0.11 % (within reason) and 1.2 % (a threat to availability). Initial 'Run 2' statistics will, however, allow for more accurate predictions.

Particle Accelerator Science and Technology Doctoral Student Award 2015

*Awarded to **Subashini De Silva***

Citation:
"For contributions to the development of a new class of superconducting structures for the deflection and crabbing of particle beams with a wide range of applications."

Ilan Ben Zvi (left) and Subashini De Silva (right).

APS DPB Outstanding Doctoral Thesis Research in Beam Physics Award 2015

*Awarded to **Agostino Marinelli***

Citation:
"In recognition of a definitive theoretical treatment of microscopic space-charge effects in particle beams, and accompanying innovative experimental tests involving the first use of coherent imaging in microbunched beams."

Steve Benson (left) and Agostino Marinelli (right).

Guide to Grant and Fellowship Opportunities in the DPB Community

Josh Einstein, Colorado State University

It's that season again—in fact that season has never left us and is constantly around. What season is this one might ask? Grant season!

Focusing on research, developing a career, or even supervising busy students can be a full-time job, and there are several programs out there that can help with the process and bring recognition to the process.

For undergraduate students, the NSF REU and DOE SULI programs offer great opportunities for research working with or in national labs across the US. In addition, several conferences, including APS, IEEE, and smaller offer opportunities for undergraduate students to present their work with travel covered. It makes for a great networking opportunity and to see what is out there.

For graduate students, the NSF, DOE, and DOD all offer research grants, and the APS FGSA offers travel awards each quarter for students to visit workshops, conferences, and to do collaborative research. With the tight funds of a graduate student, being able to afford the travel costs makes a big difference.

For early-career researchers and new graduates, thesis awards such as those from the IEEE and APS are a great opportunity to show the importance of your work while also having a chance to network. They are a great choice to apply for with recommendations. Several labs in the Unites Sates offer fellowship programs that, while competitive, provide an opportunity to work in a large collaboration and be able to focus more on research than struggling for a job. There is also a fellowship program in partnership with the LHC.

For those more interested in politics and leadership, AAAS offers positions and awards that provide the training and experience necessary to work with government. For those with such interests, the Presidential Management Fellowship and Presidential Innovation Fellowship are also good opportunities. Be very careful with deadlines on these if you're interested—they change every year and can be very tight.

There are a number of awards to honor those who have made major contributions to the field of particle accelerators. These include the Robert R. Wilson Prize, the PAST award, and the USPAS prize. Some of these prizes require nomination online.

Good luck and good hunting.

Editors note: Photos throughout this newsletter from IPAC'15 by Josh Power (www.joshpowerphotography.com). Special thanks to Josh for these excellent images.

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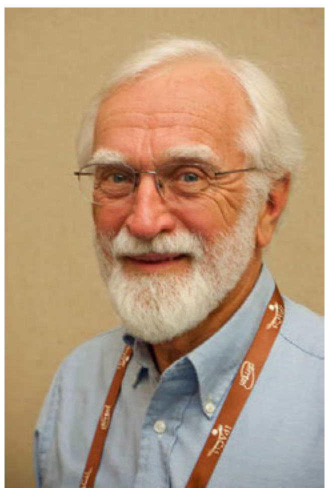

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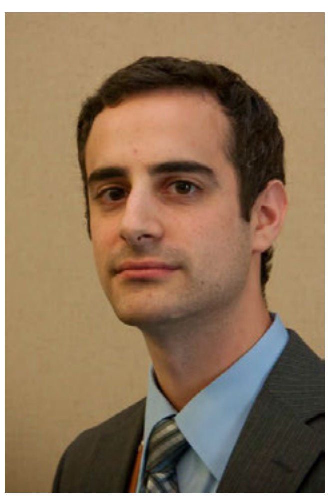

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Upcoming Meetings

July 28 - 31 2015 • **The 3rd Korea Particle Accelerator School (KoPAS 2015)** • Daejeon, Korea

August 23 - 28, 2015 • **37th International Free Electron Laser Conference (FEL 2015)** • Daejeon, Korea

September 7-11, 2015 • **13th International Conference on Heavy Ion Accelerator Technology (HIAT 2015)** • Yokohama, Japan

September 13 - 17, 2015 • **3rd International Beam Instrumentation Conference (IBIC 2015)** • Melbourne, Australia

September 13 - 18, 2015 • **17th International Conference on RF Superconductivity (SRF 2015)** • Whistler, British Columbia, Canada

September 13-20, 2015 • **2nd European Advanced Accelerator Concepts Workshop (EAAC15)** • Isola d'Elba, Italy

September 27 - October 9, 2015 • **CERN Accelerator School** • Warsaw, Poland

September 28 - October 2, 2015 • **10th International Workshop on Beam Cooling and Related Topics (COOL 2015)** • Newport News, Virginia

October 7 - 9 2015 • **International Conference on Accelerator Optimization (oPAC 2015)** • Seville, Spain

October 12 - 16, 2015 • **12th International Computational Accelerator Physics Conference, (ICAP 2015)** • Shanghai, China

October 17 - 23, 2015 • **15th International Conference on Accelerator and Large Experimental Physics Control Systems (ICALEPCS 2015)** • Melbourne, Australia

October 26 - November 6, 2015 • **9th International Accelerator School for Linear Colliders** • Whistler, British Columbia, Canada

November 2 - 6 2015 • **International Workshop on Future Linear Colliders (LCWS 2015)** • Whistler, British Columbia, Canada

November 2 - 11, 2015 • **CERN Accelerator School** • Geneva, Switzerland

December 1 - 4, 2015 • **TESLA Technology Collaboration (TTC) Meeting** • Menlo Park, California

November 10-13, 2015 • **12th International Topical Meeting on Nuclear Applications of Accelerators (AccApp '15)** • Washington, DC

January 25 - February 5, 2016 • **U.S. Particle Accelerator School (USPAS Winter 2016)** • Austin, Texas

March 14 - 18, 2016 • **APS March Meeting 2016** • Baltimore, Maryland

April 16 - 19, 2016 • **APS April Meeting 2016** • Salt Lake City, Utah

May 8 - 13, 2016 • **7th International Particle Accelerator Conference (IPAC 2016)** • Busan, Korea

June 13 - 24, 2016 • **U.S. Particle Accelerator School (USPAS Summer 2016)** • Fort Collins, Colorado

July 31 - August 5, 2016 • **Advanced Accelerator Concepts Workshop (AAC16)** • Washington, DC

September 11 - 16, 2016 • **21st International Conference on Cyclotrons and their Applications (CYCLOTRONS 2016)** • Züich, Switzerland

October 9 - 14, 2016 • **2nd North American Particle Accelerator Conference (NA-PAC 2016)** • Chicago, IL

October 30 - November 4, 2016 • **24th International Conference on Application of Accelerators in Research and Industry (CAARI 2016)** • Fort Worth, Texas