Dear Friends of CBB,

In this festive season, let’s celebrate the togetherness that makes this time of year special. In the realm of science, where individual achievements often take precedence, it’s crucial to recognize the profound impact of collaboration.

Collaborative teams are essential not only for scientific progress, but also for building science’s appeal as a career path. Some young people, often including women and members of underrepresented groups, seek a communal spirit in choosing their careers and may be deterred by a perceived culture of individualism. By embracing community, we better attract this scientific talent and bring new strength to our teams.

As we celebrate togetherness, CBB stands out for its inclusivity and collaboration. Our diverse team is a testament to this commitment. In the holiday spirit, let’s cherish our unity and the richness that community brings to our shared journey.

Wishing you joyous holidays!

J. Ritchie Patterson
Director of the Center for Bright Beams
The theoretical and experimental advancements in the performance of Nb₃Sn-coated cavities make them a promising approach for future accelerators but there is still a need for a thorough understanding of how to grow higher quality Nb₃Sn alloy films.

"Advancing this science is only made possible through diverse collaborations - an important focus at the heart of CBB. The expertise and close collaborations between all of our partner institutions are driving this research into the future."

Ritchie Patterson, Director of CBB

This new CBB research, conducted by experimental materials chemists at the University of Chicago coupled with theoretical physicists at the University of Florida, delivers the first atomic-scale images of Sn on oxidized niobium, depicting the early stages of Nb₃Sn formation. This visualization of Sn adsorption and diffusion on oxidized niobium is an essential advancement in creating a mechanistic formula for optimizing the fabrication of next generation accelerator cavities.

“The quality and accelerating performance of Nb₃Sn depends on many convoluted variables at play during the growth procedure" says Sarah Willson, CBB graduate student at the University of Chicago and co-lead author of the paper along with postdoctoral scholar Rachael Farber. "We are aiming to look at the initial steps of a complicated growth process and isolate certain variables in a controlled setting.” Their atomic-level growth experiments are supported by quantum theory from graduate student Ajinkya Hire.

As Nb₃Sn accelerator cavities are prepared, scientists aim to reduce impurities and contaminants from the niobium cavity to achieve a cleaner and more uniform surface. The cavity is then heated to high temperatures in the presence of an Sn vapor. This causes the Sn to diffuse into the Nb layer, forming Nb₃Sn. As careful measures are taken to grow a pristine Nb₃Sn film, looking closely across the cavity reveals a highly disordered, rough, polycrystalline surface - not the consistent single-crystal surface ideal for a highly controlled experiment.

Willson explains that in order to conduct this experiment, they recreate, in a way, the real-world process of cavity-making, but further surpass the temperature demands needed - heating the materials to 1630 degrees Celsius, and creating an atomically-flat niobium oxide surface to showcase the interactions of Sn, Nb, and O at the atomic level.

Observations of metal oxides are routinely performed using scanning tunneling microscopy, STM, revealing information at the atomic scale. However, the specific setup for studying Nb₃Sn growth with STM is not readily available. So, Willson and Farber created one. They designed and built a custom metal deposition chamber to deposit the Sn on the niobium surface. This technique recreates the real-world environment in which accelerator cavities are developed – with the ability to prevent surface contamination – while allowing researchers to study the deposition using STM.

“We have taken a state-of-the-art STM setup, which was not really built to study high temperature metallic growth and alloy formation, but through the funds from CBB, have added the intermetallic growth chamber that allows us to do these experiments in-situ,” says Willson, stating that using the intermetallic growth section reveals the individual Sn atoms integrating with the niobium subsurface.

“We see that even in our highly-controlled environment, the Nb surface serves as a major roadblock in preventing Sn diffusion required for Nb₃Sn formation,” says Willson. “Improving Nb₃Sn growth is much more than just simply developing a uniform coating layer of tin on niobium.”

This study was led by corresponding author Steven Sibener, Carl William Eisenbrauth Distinguished Service Professor at the University of Chicago, in collaboration with CBB faculty member Richard Hennig, Alumni Professor of Materials Science and Engineering at the University of Florida.

Sibener, a physical chemist, says that the collaboration between different areas of accelerator and non-accelerator sciences is unique in his experience, helping to lay the groundwork for advancing particle accelerators and looks forward to the promising developments of Nb₃Sn.

“The collaborations that CBB sparks, the ability for surface chemists, materials engineers, accelerator physicists, and theorists to interact in this way, has certainly empowered and strengthened this research,” says Willson. “Personally, I gained a deeper understanding of how to properly navigate the challenges associated with the differing jargon, priorities, and research perspectives across scientific fields. Many chemists are interested in these types of interfacial metallic growth challenges that are encountered by engineers and physicists. This collaboration facilitated extensive interdisciplinary communication that has made conducting a study like this more comfortable and efficient.”
Mean Transverse Energy at the Thermal Limit


The Mean Transverse Energy (MTE) of Cs\textsubscript{3}Sb has been shown to approach the thermal limit at room temperature when illuminated with light at the emission threshold. The emission threshold was observed to be lower than in previous studies. MTE is the ultimate limit on the achievable brightness of an electron source. If this performance can be replicated in a full injector with a higher QE, it will enable hard X-ray operation of LCLS-II HE.

Unlocking the Potential of CsSb Thin Films for High-Brightness Electron Beams


Here, we investigate the growth of Cs\textsubscript{3}Sb photocathodes over a variety of compositions, in situ electron diffraction, we identify the growth conditions for atomically smooth CsSb films on substrates including 3C-SiC (100) and graphene-coated TiO\textsubscript{2} (110). A variety of in situ probes including XPS, ARPES, and STM provide a comprehensive picture of the structural, morphological, and electronic properties of the resulting films.

Detailed four-dimensional transverse phase space reconstruction using neural networks and differentiable simulations

R. Roussel, A. Edelen, C. Mayes, D. Ratner, J. P. Gonzalez-Aguilera, S. Kim, E. Winnikowski, and J. Power

In this work, we present a new algorithm that makes use of neural networks and differentiable particle tracking simulations to efficiently reconstruct 4D transverse phase space distributions. The reconstruction only needs a single focusing quadrupole, a diagnostic screen and a limited number of measurements. We demonstrate an unprecedented level of reconstruction detail in both experimental and simulated examples.

Smooth, homogenous Nb\textsubscript{3}Sn


Superconducting thin films, e.g., Nb\textsubscript{3}Sn, are the next generation materials for RF accelerator cavities. However, the large surface roughness and non-stoichiometry of Nb\textsubscript{3}Sn are two critical issues that limit their RF performance. Here, we achieved smooth, homogenous Nb\textsubscript{3}Sn through our novel electrochemical recipes. The resultant surface roughness is five time smaller than the values from conventional vapor diffusion.

Unveiling the Secrets of Atomic Surface Scattering: A Universal Approach from First Principles

M. M. Kelley, R. Sundararaman, and T. A. Arias

This revolutionary study fills that void by introducing a new, fully first-principles framework by explicitly evaluating the interactions between the scattering atom and the surface electrons. By doing so, this new method corrects misleading results from previous theories and overall provides a more accurate approach for understanding atom–surface interactions.

More Research Highlights:

cbb.cornell.edu/research/research-highlights
New Partnership with Morgan State University

We are excited to announce a new partnership with Morgan State University and Dr. Willie Rockward, the Chair and Professor of Physics & Engineering Physics. Morgan State is Maryland’s preeminent public urban research university and an HBCU. Their Department of Physics holds a vision to be a leader in producing the best and the brightest in Physics and we are thrilled to have them join the CBB team.

Through the Advancing Scientific exCELlence by Empowering Research in Accelerators Through Education (ACCELERATE) program, students from Morgan State will participate in CBB research. Projects may include developing photocathode materials or studying the impact of defects or surface roughness on the superconducting properties of RF accelerating cavities.

Welcome Morgan State!

Collaboration and Global Research

Young-Kee Kim, the Louis Block Distinguished Service Professor at University of Chicago, and CBB theme leader gave a keynote speech at the World Congress of Korean Scientists & Engineers emphasizing the importance of forging more research connections.

By Baek Byung-yeul as seen in The Korea Times

Korean scientists and researchers from around the world gathered in Seoul, Wednesday, to interact with scholars and researchers at the inaugural World Congress of Korean Scientists & Engineers. To advance, Korea’s science and technology, they also emphasized the importance of forging more connections with global researchers.

“It is important for Korean researchers to collaborate with international research organizations and pursue diverse kinds of human resource exchange,” Young-Kee Kim, a physics professor at the University of Chicago, said during the event, introducing research about particle accelerator conducted in collaboration with countries around the world.

“We are very grateful to the president for fulfilling his promise to invite Korean researchers from around the world for exchanges. We have already laid the foundation for cooperation as ‘world Koreans’ and will continue to provide systematic cooperation and support for ‘global Korea’ as leaders in science and technology,” Kim said.

To read the full press release: [The Korea Times](#)

CBB at the National Society of Black Physicists Conference

The National Society of Black Physicists (NSBP) is the leading professional organization for the African-American physics community. It creates and supports initiatives that broaden opportunities for African Americans in physics, striving to increase their representation in the field. CBB joined this year’s meeting on November 9 – 12 in Knoxville, TN.

CBB postdoctoral fellow, Elena Echeverria, and Michigan State University Professor, Paul Guèye, organized a “Science Hour” to raise awareness about Accelerator Sciences and its applications. CBB Director, Ritchie Patterson, presented “Bright Electron Beams for Science and Society.” Other speakers were Thomas Glasmacher, Director of Michigan State University’s Facility for Rare Isotope Beams, and Julianne Pollard-Larkin of the MD Anderson Cancer Center.

NSBP Science Hour attendees, including (from front row, second from left) Ritchie Patterson, Julianne Pollard-Larkin, Elena Echeverria, distinguished accelerator scientist Sekazi Mtingwa, and behind him, Paul Guèye.
Welcome New CBB Members

Graduate Students

Eric Cropp
Postdoctoral Fellow
SLAC National Accelerator Lab
Thesis: High-Performance Accelerator Modeling: Toward Improving Controls and Diagnostics for High-Brightness Beams in Experiment

AJ Dick
Postdoctoral Fellow
Argonne National Lab
Thesis: Computational Modeling and Simulation of Optical Stochastic Cooling

Michelle Kelley
Postdoctoral Fellow
Rensselaer Polytechnic Institute

Pallavi Saha
Postdoctoral Fellow
Brookhaven National Lab
Thesis: Growth and Characterization of Cesium-antimondite Photocathodes

More Alumni and
Where they are now:
cbb.cornell.edu/about/cbb-alumni

Postdocs

Nathan Majernik
Staff Scientist
SLAC National Accelerator Lab

Zeming Sun
Research Assistant
Bruker Biotechnology Research

Nathan Sitaraman
Postdoctoral Fellow
Cornell University
Thesis: SRF Theory Work on SRF Materials

Recent Alumni

Gevork Gevorkyan
Postdoctoral Fellow
Mayo Clinic
Thesis: Brightness, Spin Polarization, and Lifetime of Photocathodes for a High Current Electron Beam

Chris Knill
Advanced R&D Scientist
Honeywell ACST
Thesis: Practical Limitations of Low Mean Transverse Energy Metallic Photocathodes

Nathan Majernik
Postdoctoral Fellow
SLAC National Accelerator Lab

Zeming Sun
Research Assistant
Bruker Biotechnology Research

Prof. Willie Rockward
Chair of Physics and Engineering Physics
Morgan State University

Recent Alumni

Priyadarshini Bhattacharyya
Graduate Student
Arizona State University
Beam Production

Sergei Kladov
Graduate Student
University of Chicago
Beam Dynamics and Control

More Alumni and
Where they are now:
cbb.cornell.edu/about/cbb-alumni

New Partner

Fabio Bosco
Postdoctoral Fellow
UCLA
Beam Dynamics and Control

Van Do
Graduate Student
University of Chicago
Beam Production

Emily Frame
Graduate Student
Northern Illinois University
Beam Dynamics and Control

Sam Dong
Graduate Student
University of Florida
Beam Production

Azriel Finsterer
Graduate Student
Cornell University
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Tariqul Hasan
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Monika Yadav
Postdoctoral Fellow
UCLA
Beam Dynamics & Control

Fabio Bosco
Postdoctoral Fellow
UCLA
Beam Dynamics and Control

Van Do
Graduate Student
University of Chicago
Beam Acceleration

Sam Dong
Graduate Student
University of Florida
Beam Acceleration

Azriel Finsterer
Graduate Student
Cornell University
Beam Acceleration

Tariqul Hasan
Graduate Student
Northern Illinois University
Beam Acceleration

Daniel Franklin
Graduate Student
Northern Illinois University
Beam Acceleration

Emily Frame
Graduate Student
Northern Illinois University
Beam Acceleration

Monika Yadav
Postdoctoral Fellow
UCLA
Beam Dynamics & Control

Charles Zhang
Graduate Student
Cornell University
Beam Production
2023 Annual Meeting and Symposium

The 2023 Annual Collaboration Meeting and Symposium was held at Cornell University in July. This is the one time each year when we meet in person. In addition to research-centric talks, presentations, learning 3-D design with Fusion360, and poster sessions, we spent time in real life (IRL) hiking, bowling, rock climbing, and even competing in a team-based scavenger hunt.

Hobbes! The Pawsitive Vibe Generator at CBB.

Congratulations to Poster Session Winners!

Juan Pablo Gonzalez Aguilera: “Towards fully differentiable accelerator modeling”


Chad Pennington: “Ultra-thin Cs3Sb Photocathodes with Anomalously High Quantum Efficiency”

Liana Shpani: “Optimizing Growth of Niobium-3 Tin Through Pre-nucleation Chemical Treatments”

Professor David Muller gave a fascinating ethics talk from his experience at Stanford “Fundamental principles of scientific research and the rise and fall of Jan Hendrik Schön”

Postdoctoral Fellow Elena Echeveria taught our team the Basics of Photocathode Characterization Techniques

Watch on our YouTube Channel!

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CBB graduate student, Sarah Willson, presents a 60-second research blitz.

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Research Experiences for Undergraduates

**Contribute** to cutting-edge research at world leading institutions.

**Experience** interdisciplinary research, working side-by-side with material scientists, chemists, condensed matter physicists and accelerator scientists.

**Learn** alongside individuals from a wide range of nationalities, cultures and educational backgrounds. CBB continuously works toward the inclusion of underrepresented minorities, women, and first-generation students.

**Explore** high demand career opportunities.

CBB strives to broaden the pipeline of accelerator scientists by increasing awareness of the discipline beyond the walls of national accelerator laboratories and by actively seeking out the participation of students and senior researchers from underrepresented groups. The Research Experience for Undergraduates (REU) has been a key component of this goal. Brigham Young University, University of Chicago, Cornell University, and Northern Illinois University regularly host CBB REU programs each summer. **We are currently accepting applications for the 2024 REU Program.**

Check out what a few of our past students had to say.

**Taylor Ray ’23**
Northern Arizona University

"This experience really made me realize that this is what I want to do. I saw how collaborative science research can be, and how amazing it is to be surrounded by people who are as passionate as you about a subject. I also realized, however, that being a researcher is very draining at times. I feel motivated to develop some self-care techniques in order to work hard without burning out at the end of the day."

Full Interview.

**Ritee Zahin ’23**
Adelphi University

"What I’m enjoying most of all is the knowledge that I’m getting, it’s a big thing for me. I love physics and I have never learned like this before in my normal classes. That’s most important to me. And the other thing is the group we have here and the connection we have."

Full Interview.

Watch Ritee’s full interview about the 2023 Summer Program here.
We invite you to explore and share the comprehensive guides & Lending Kits available on CBB’s Resources for Teachers webpage.

Exciting Physics Workshop Empowers Arizona Educators!
In collaboration with the Arizona Teachers Association, the Center for Bright Beams recently hosted an engaging physics workshop for 23 dedicated K-12 teachers hailing from various corners of Arizona.

The event, led by Professor Karkare along with CBB graduate students and postdocs, immersed the educators in a series of hands-on activities designed for seamless integration into their K-12 classroom curricula.

Among the highlights were innovative experiments crafted by CBB’s scientists, such as “What is a Wave?” These experiments enable teachers to captivate their students’ imaginations through immersive experiences involving sound, water, and a wave machine, fostering an understanding of the fascinating world of waves.

Additionally, teachers delved into the mysteries of Newton’s Laws of Motion by constructing airboats and investigating how various variables influence their motion.

An inspiring visit to ASU’s groundbreaking Compact X-ray Free Electron Laser (CXFEL), the world’s first of its kind, added a touch of cutting-edge science to the workshop.

Outreach Updates

Expanding Your Horizons

The Center for Bright Beams is an annual sponsor of Expanding Your Horizons at Cornell University. In April 2023, 28 workshops were offered to over 230 middle-school students. These hands-on activities led by scientist role models help young students learn that anyone with a curious mind has what it takes to pursue a future in STEM!

2023 EYH student evaluations noted:
“It brought me interest in a type of science I didn’t know about before.”
“It has taught me that there is a lot more to science than I thought. I learned about a lot more topics that I never knew about.”
“My favorite part of the conference was learning about the people and how they got to where they are.”

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2023 – 2024 Projects

<table>
<thead>
<tr>
<th>PI Name</th>
<th>Projects</th>
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<tbody>
<tr>
<td>Ares</td>
<td>Ab initio theory of many-body photoinjection and of photocathodes</td>
</tr>
<tr>
<td>Ares</td>
<td>Ab initio exploration of beyond-Nb SRF materials for low cooling power and high field performance</td>
</tr>
<tr>
<td>Ardey</td>
<td>Applications of Machine Learning in Photoinjectors</td>
</tr>
<tr>
<td>Chubenko</td>
<td>Photocathodes under realistic accelerator conditions</td>
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<tr>
<td>Chubenko</td>
<td>Monte Carlo modeling of photoinjection from semiconductors</td>
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<tr>
<td>Hering</td>
<td>Quantum machine-learning for the synthesis of photocathodes by optical growth</td>
</tr>
<tr>
<td>Hering</td>
<td>Thermodynamics and Superconducting Properties of Novel SRF Superconductors</td>
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<tr>
<td>Hines</td>
<td>Air-stable, high performance photocathodes</td>
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<tr>
<td>Hoffstaetter</td>
<td>BDC/Center for Research: High-Performance Nb ₃Sn SRF Liana Shpani (GRA)</td>
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<td>Liepe</td>
<td>Elastoplastic characterization of Nb ₃Sn films</td>
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<td>Sibener</td>
<td>Optimization of Nb ₃Sn Surfaces: Atomic Visualization of Alloy Growth and Oxide Suppression</td>
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<tr>
<td>Transtrum</td>
<td>Mesoscopic models of superconductivity for realistic materials and surfaces</td>
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Awards and Honors

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<tr>
<th>Recipient</th>
<th>Award name or sponsor</th>
<th>Reason for award</th>
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<tbody>
<tr>
<td>Juan Pablo Gonzalez Aguilera</td>
<td>Physical Sciences Division Quarter Fellowship, U. Chicago</td>
<td>For strong academic potential</td>
<td>2023</td>
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<tr>
<td>Afnan Al Marzouk</td>
<td>Graduate School, Northern Illinois U.</td>
<td>Outstanding Dissertation Award of 2021-2022 in STEM and health sciences</td>
<td>2022</td>
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<tr>
<td>Zhaslan Baraisov</td>
<td>2023 Student Scholar Award, Microscopy &amp; Microanalysis</td>
<td>Best Paper</td>
<td>2023</td>
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<tr>
<td>AJ Dick</td>
<td>Graduate School, Dept. of Physics, Northern Illinois U.</td>
<td>Outstanding Graduate Student</td>
<td>2022</td>
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<tr>
<td>Gevork Gevorkyan</td>
<td>Innovation Fellowship, Grad Student and Professional Student Association, Arizona State U.</td>
<td>Forming and hosting an interdisciplinary graduate colloquium series</td>
<td>2022</td>
</tr>
<tr>
<td>Alimohammed Kachwala</td>
<td>Graduate and Professional Student Association, Arizona State U.</td>
<td>Outstanding Research Award</td>
<td>2022</td>
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<tr>
<td>Alimohammed Kachwala</td>
<td>Graduate and Professional Student Association, Arizona State U.</td>
<td>Outstanding Mentor Award</td>
<td>2022</td>
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<tr>
<td>Alimohammed Kachwala</td>
<td>William J. and Carol M. Motil Scholarship For Experimental Research</td>
<td>2022</td>
<td></td>
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<tr>
<td>Michelle Kelley</td>
<td>Psi-k conference</td>
<td>Poster commendation</td>
<td>2022</td>
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<td>Jared Maxson</td>
<td>Stephen and Margery Russell Distinguished Teaching Award</td>
<td>Devotion to teaching</td>
<td>2023</td>
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<tr>
<td>David Muller</td>
<td>2023 John Cowley Medal, International Microscopy Congress</td>
<td>Lifetime achievement</td>
<td>2023</td>
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<tr>
<td>David Muller</td>
<td>American Association for the Advancement of Science</td>
<td>Career achievement in plasma science</td>
<td>2023</td>
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<tr>
<td>James Rosenzweig</td>
<td>2023 Hannes Alven Prize in Plasma Physics, European Physical Society</td>
<td>Career achievement in plasma acceleration</td>
<td>2023</td>
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<tr>
<td>Kyle Shen</td>
<td>APS, Division of Materials Physics</td>
<td>Fellow</td>
<td>2022</td>
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<tr>
<td>Liana Shpani</td>
<td>Early Career Investigator Award, 21st International Conference on Radio-Frequency Superconductivity</td>
<td>Best Oral Presentation</td>
<td>2023</td>
</tr>
<tr>
<td>Steve Silbiger</td>
<td>Remsen Award, American Chemical Society</td>
<td>Lifetime achievement</td>
<td>2023</td>
</tr>
<tr>
<td>Mark Transtrum</td>
<td>Edward and Betty Seppi Endowed Chair of Physical and Mathematical Sciences.</td>
<td>Demonstrated potential for future research excellence.</td>
<td>2022</td>
</tr>
</tbody>
</table>
CBB Impact in the Global Accelerator Community

CBB participated broadly in conferences, workshops, and events around the world reaching audiences in not only the accelerator community but also in the broader scientific community.

CBB Students and Postdocs presented
25 Research talks
36 Scientific Posters

CBB Faculty served on
16 Conference and Workshop Organizing Committees
8 Advisory Committees
3 Review Committees
4 Community Planning Committees

CBB Accelerator Research Training Videos received
Over 15k views from 12 Pedagogical videos
Over 4k views from 8 Professional Development videos

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Recent Publications

Full publications list online at https://cbb.cornell.edu/publications


Recent Publications


Recent Publications


Patents


