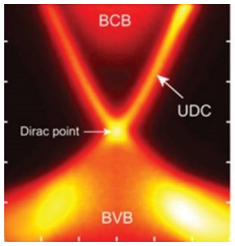
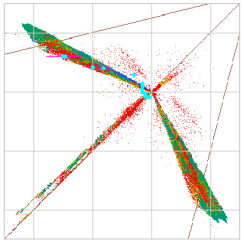
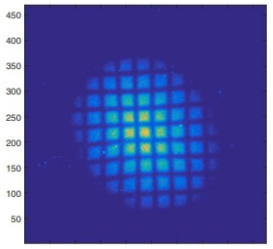
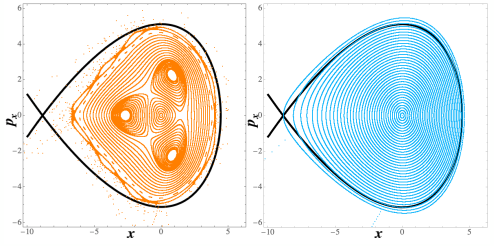
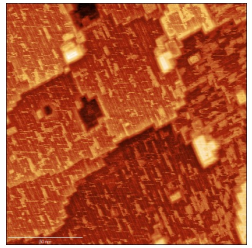
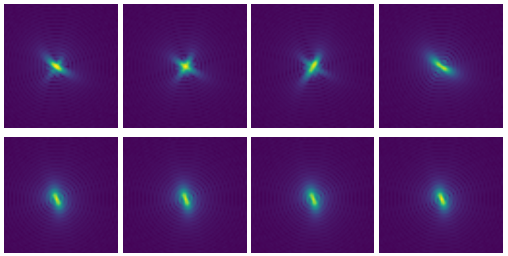
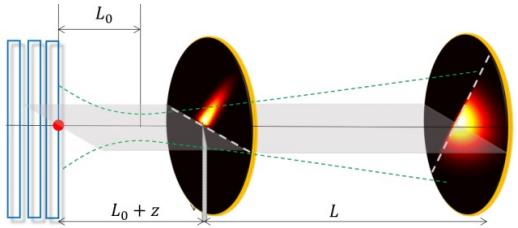
The Center for
BRIGHTBEAMS
A National Science Foundation Science & Technology Center

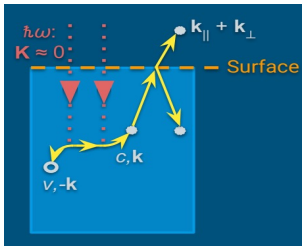
Overview
Site Visit 2022

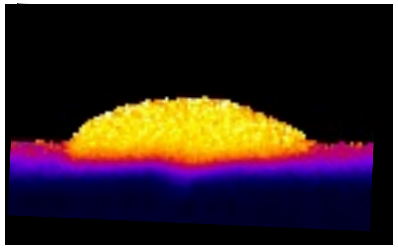
J. Ritchie Patterson
Center Director







Safety Precautions

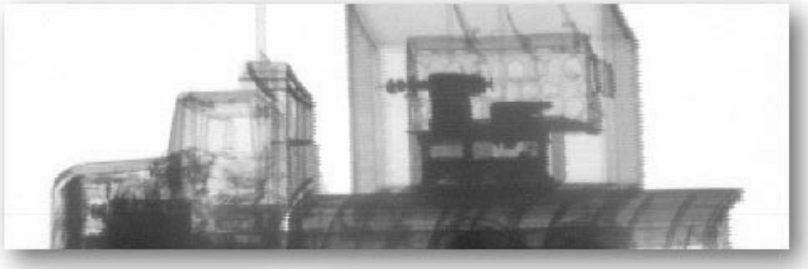
- Masks are available for anyone who wants one

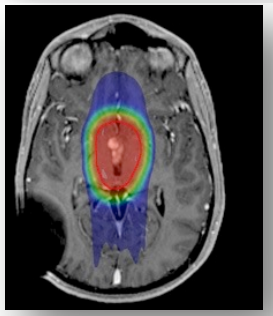
- Please stay away if you're sick

- Exits: Stairs are to the right of the elevators or continue past the stairs across the bridge to Clark Hall

Why accelerators?

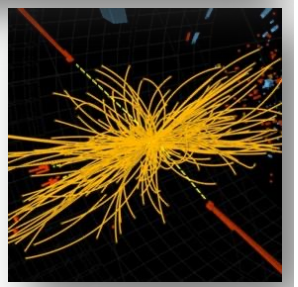
- Industry
  - Food & product safety
  - Contraband detection
  - Polymer cross-linking, eg tires
  - Semiconductor fabrication
- Medicine
  - Medical isotope production
  - Tumor treatment





~30,000 industrial and medical accelerators are in use, with annual sales of $3.5 B and 10% growth per year.

- Research
  - X ray sources and colliders for nuclear & particle physics
  - Electron microscopes



Since 1943, a Nobel Prize in **Physics** has been awarded to research benefiting from accelerators every 3 years.

Since 1997, the same has been true of **Chemistry**.

Center for Bright Beams - CBB

Center Vision:

Gain the fundamental understanding needed to transform the brightness of beams available to science, medicine and industry.

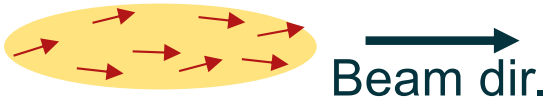
Center Mission:

- Increase beam brightness x100 and reduce cost and size.
- Transfer key technologies to national labs and US industry.
- Prepare a diverse group of students for leadership.

The annual demand for new Accelerator Science and Technology PhDs by DOE labs is 2-3x the number produced by US universities.

HEPAP Subcommittee for Review of US Particle Accelerator School (2015).

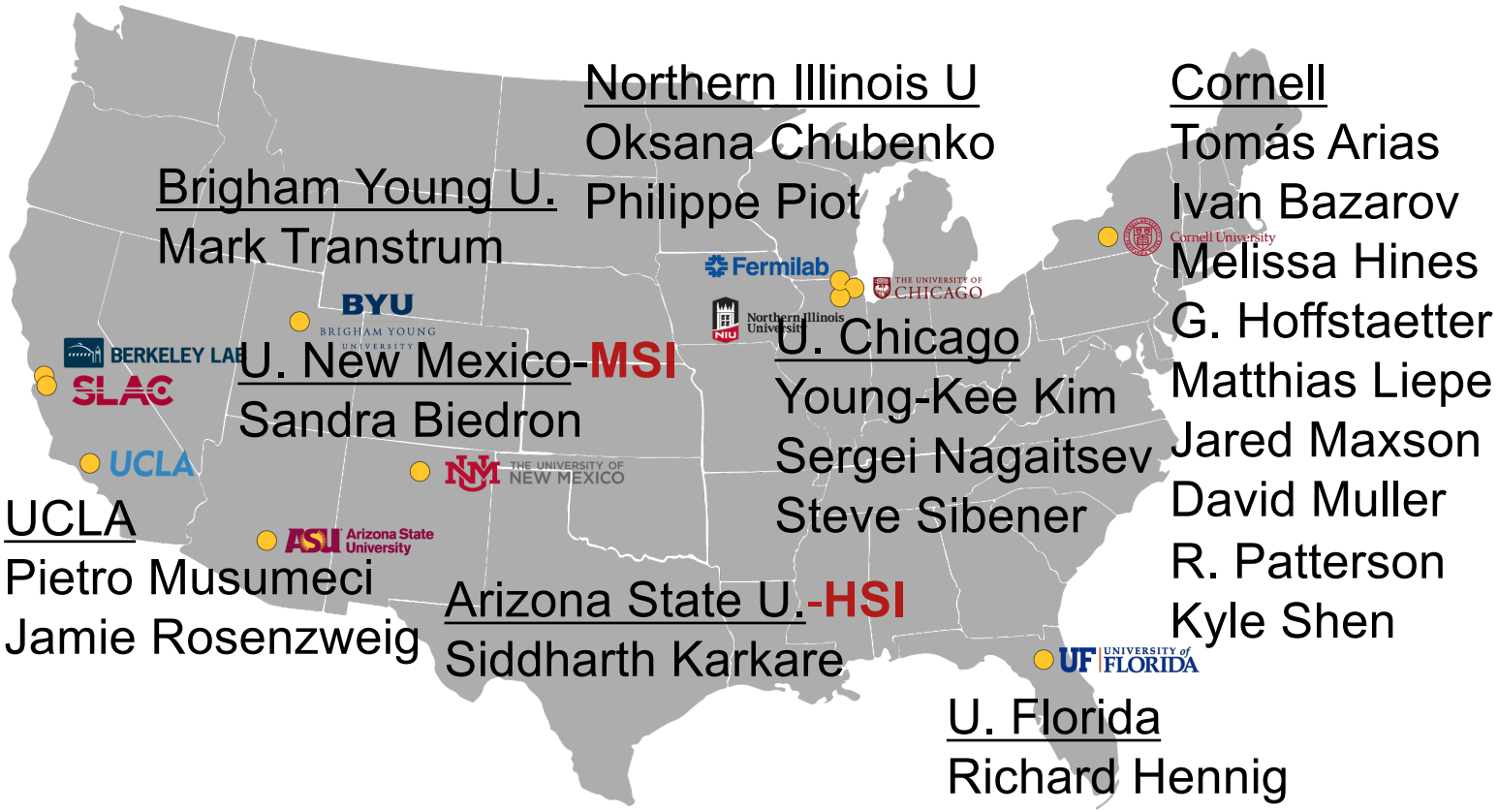
What is brightness?



Low brightness bunch

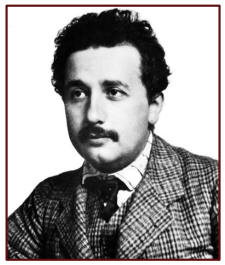
High brightness bunch

CBB institutions

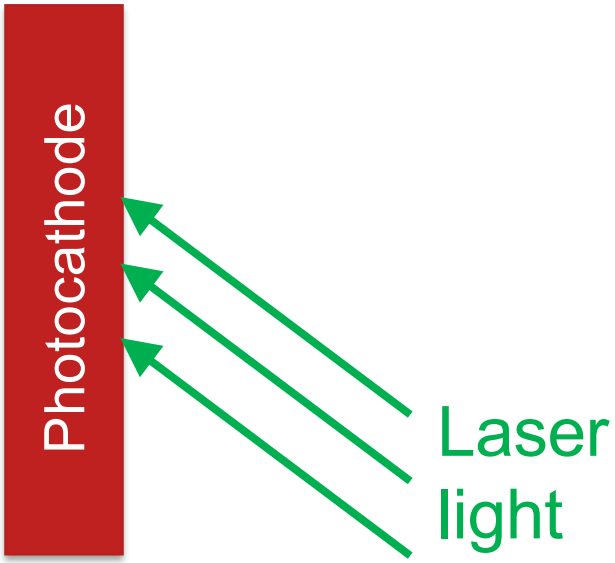


CBB joins chemists, surface scientists, condensed matter physicists, ab initio physicists, electron microscopists, and accelerator scientists

Accomplishment: Better beam production



Einstein
1905



Earlier: CBB showed that for optimal performance, the photocathode must be a single crystal semiconductor

2022: We grew one!
Smooth epitaxial Cs_3Sb

*PRL **128**, 114801 (2022)*
Editor's Suggestion
Featured in Physics

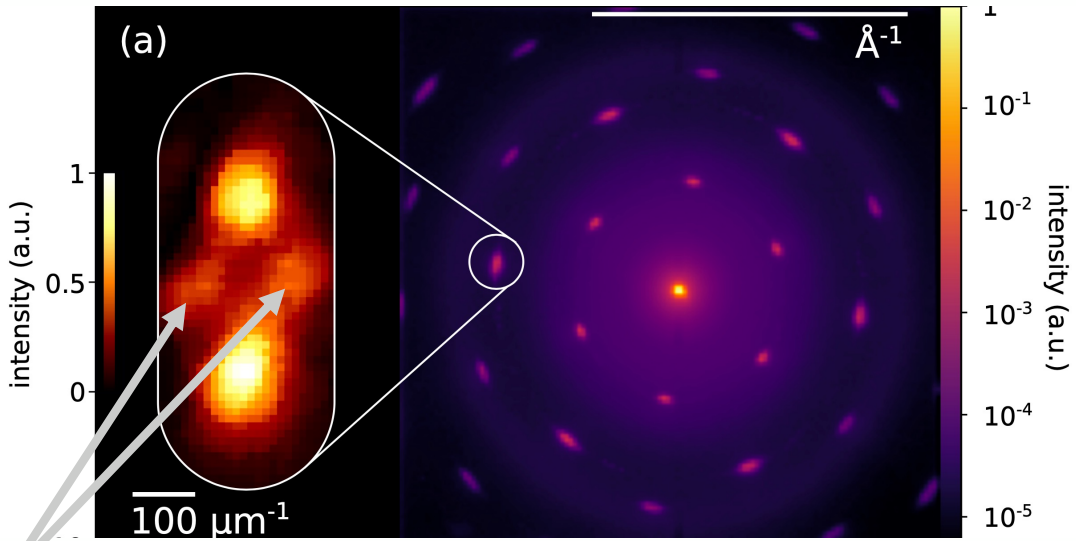
CBB is now transferring this know-how to SLAC so they can use these cathodes in their X-ray FEL upgrade

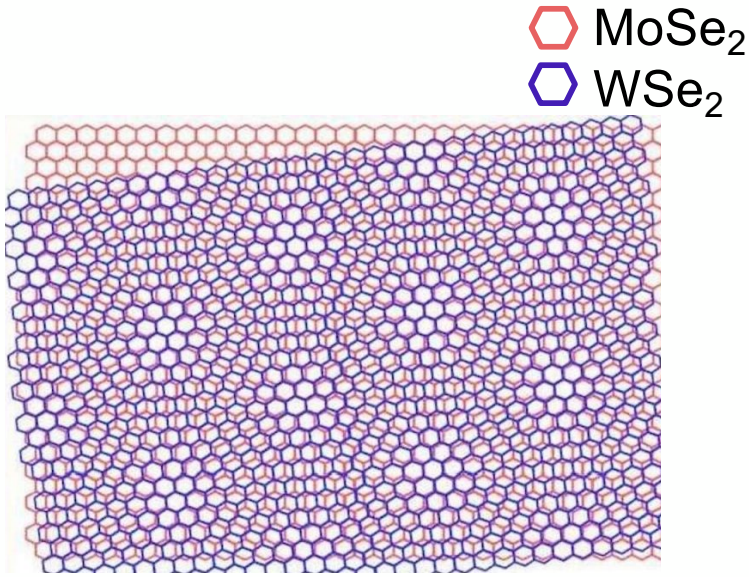
Impact: increased energy reach of SLAC LCLS-II-HE X-rays

Team: Surface chemistry, electron microscopy, accelerator science, ab initio physics, materials engineering, condensed matter physics, and computational physics.

Accomplishment: Better UED

Single hexagonal atomic layers → twist → Moiré pattern





10 nm periodicity of the Moiré superlattice.
First observation in an ultrafast setup

Large coherence length (10 nm)
enabled by a near-ideal beam
Arxiv: 2206.08404

Tech Details

- MEDUSA UED Beamline (Cornell)
  1kz rep rate
- EMPAD high dynamic range
  detector

Accomplishment: Microscope tuning

Nion UltraSTEM microscope
Atom-scale imaging

Earlier: CBB showed that microscope tuning can be cast as an emittance minimization problem.

2022: We used machine learning to tune the octupole aberration corrector (81 lenses)

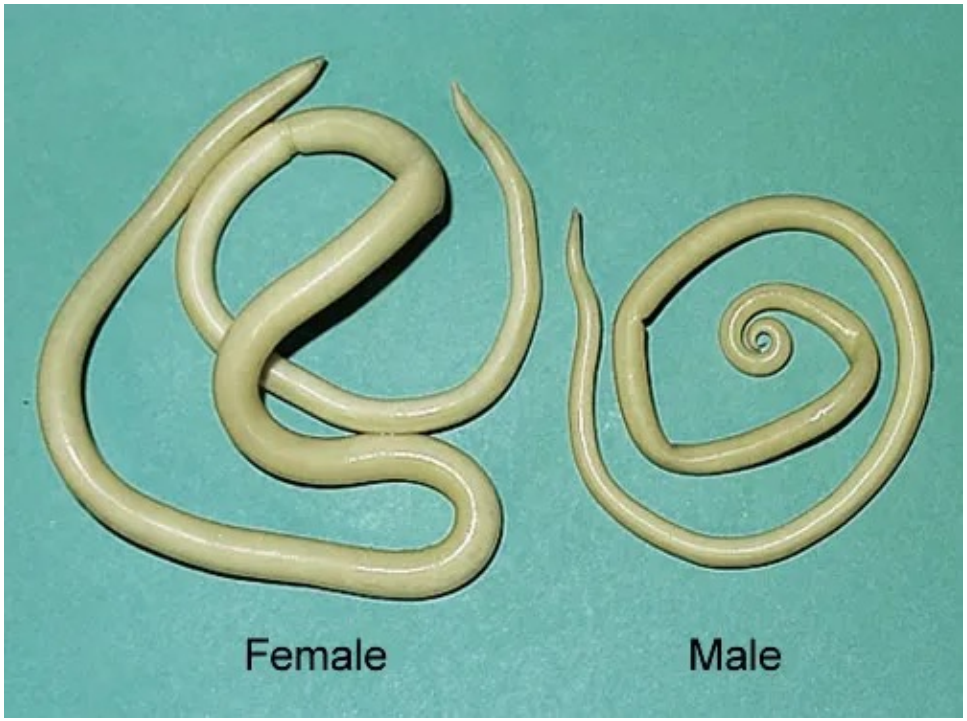
Microsc. Microanal. ***28*** *(S1), 3146 (2022)*

Automated tuning performs as **well or better** than standard tuning, is **faster** (2 minutes), and **doesn't rely on human judgement**

For better performance from electron microscopes

Enabled by an interdisciplinary team

Sewage



Round worms

Ascaris lumbracoides

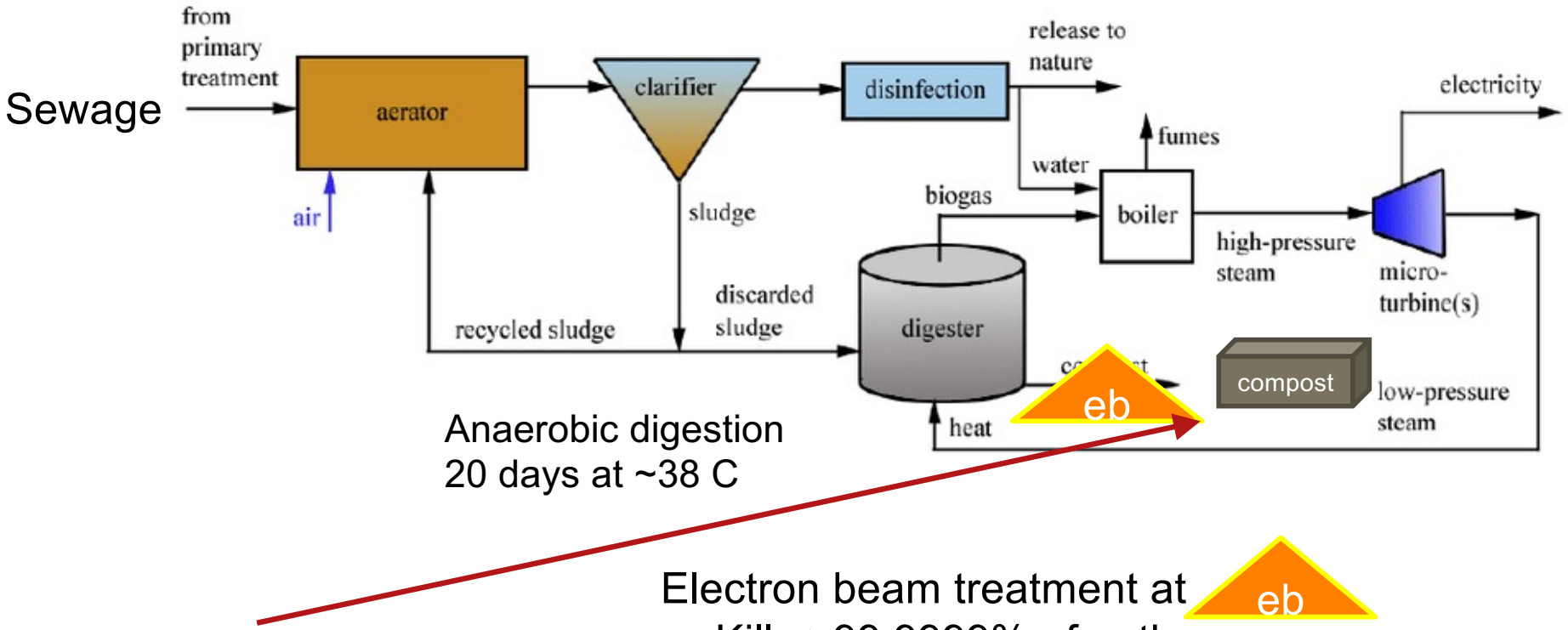
Found in human intestines

- World population 22%
- US population 2%

Eggs are in feces and enter sewage

See Rob Edgecock, *Applications of Particle Accelerators*
https://www.youtube.com/watch?v=-eOem2-d6AU

Sludge



Output compost
Low-grade fertilizer, not suitable for food crops

Electron beam treatment at eb

- Kills >99.9999% of pathogens
- Inactivates parasite ova
- Breaks down pharmaceuticals, etc.
- Produces microbiologically safe fertilizer

Pilot plants are under construction in Poland and China

CBB innovations are making needed high-power electron beams a reality.

Accomplishment: Better sludge tech

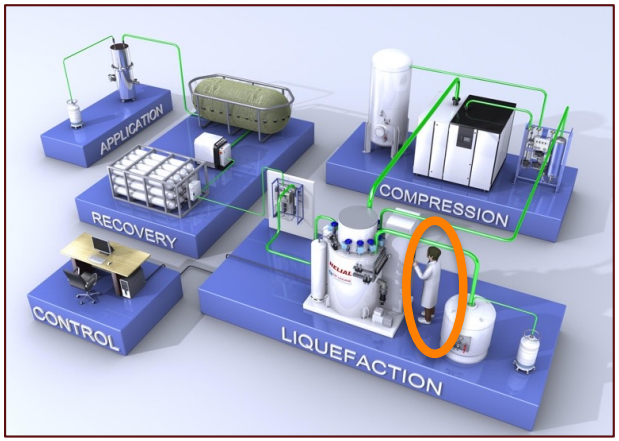
Superconducting RF (SRF) cavities: the standard for beam acceleration.

Niobium

CBB has enabled a different superconductor with a higher, far easier to manage, critical temperature

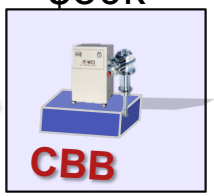
→ A beam in every basement
... or sewage plant

~$1M



Cooling for one cavity

$50k



Transfer of this tech to FNAL and TJNAF is well-established

Team: Surface chemistry, electron microscopy, accelerator science, ab initio physics, materials engineering, condensed matter physics, and computational physics.

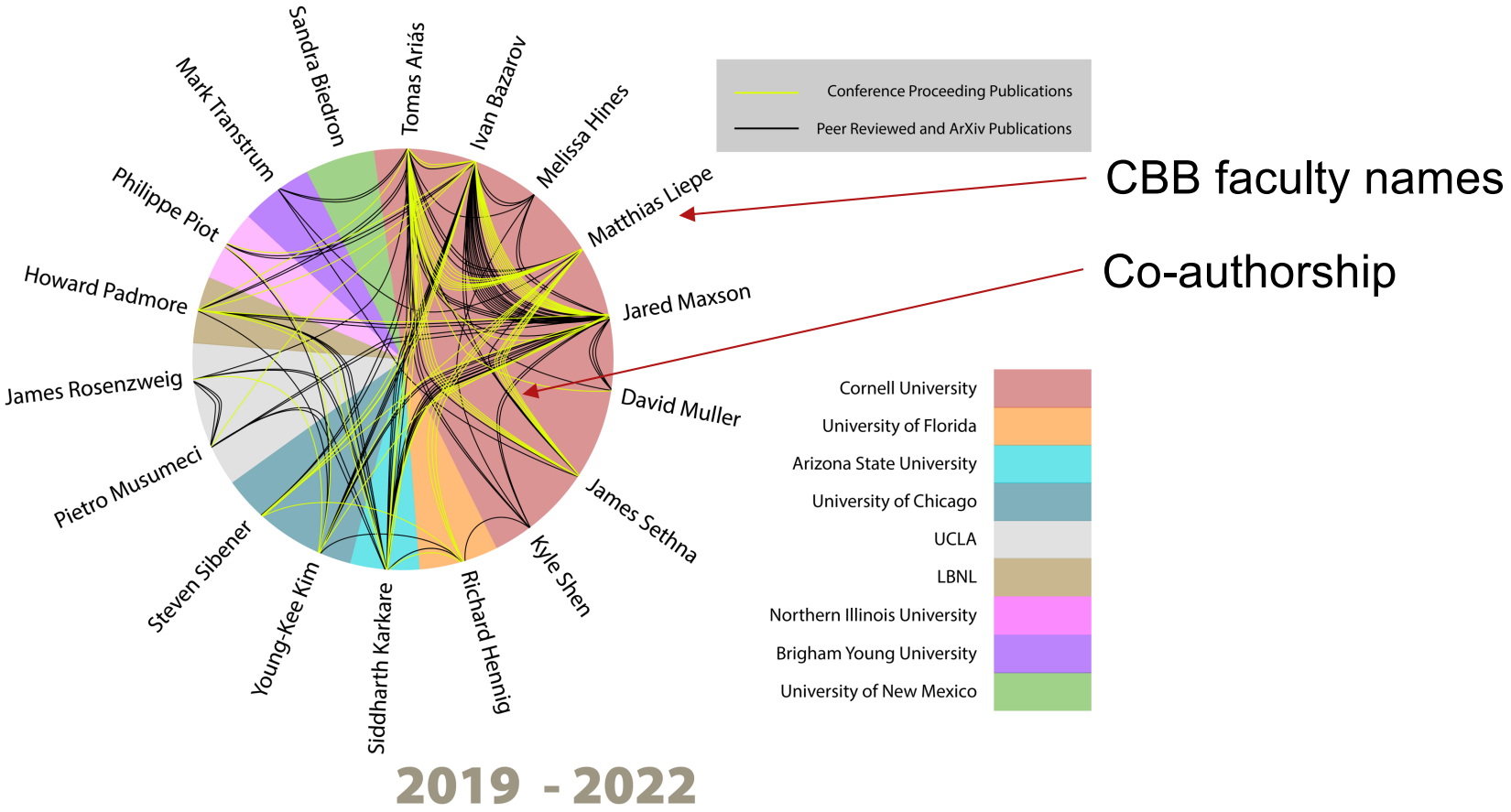
Pubs/proceedings this year

Colors show the univ. **departments/institutions** of the authors.

P. Denham and P. Musumeci, “Analytical Scaling Laws for Radiofrequency Based Pulse Compression in Ultrafast Electron Diffraction Beamlines.” arXiv, Jun. 03, 2021	UCLA
M. Gordon, S. B. van der Geer, J. Maxson, and Y.-K. Kim, “Point-to-point Coulomb effects in high brightness photoelectron beam lines for ultrafast electron diffraction,” *Phys. Rev. Accel. Beams*, vol. 24, no. 8, p. 084202, Aug. 2021	Chicago LEPP
A. Dick, J. Jarvis, and P. Piot, “Characterization of the Sub-mm Delay Plates for the IOTA Optical-Stochastic-Cooling Experiment,” FERMILAB-FN-1130-AD, 1827262, oai:inspirehep.net:1950815, Jul. 2021	NIU FNAL
L. Cultrera, E. Rocco, F. Shahedipour-Sandvik, L. D. Bell, J. K. Bae, I. V. Bazarov, P. Saha, S. Karkare, and A. Arjunan, “Photoemission characterization of N-polar III-nitride photocathodes as candidate bright electron beam sources for accelerator applications,” *Journal of Applied Physics*, vol. 131, no. 12, p. 124902, Mar. 2022	BNL LASSP LEPP ASU
A. A. McMillan, C. J. Thompson, M. M. Kelley, J. D. Graham, T. A. Arias, and S. J. Sibener, “A combined helium atom scattering and density-functional theory study of the Nb(100) surface oxide reconstruction: Phonon band structures and vibrational dynamics,” *J. Chem. Phys.*, vol. 156, no. 12, p. 124702, Mar. 2022	Chicago LASSP
C. T. Parzyck, A. Galdi, J. K. Nangoi, W. J. I. DeBenedetti, J. Balajka, B. D. Faeth, H. Paik, C. Hu, T. A. Arias, M. A. Hines, D. G. Schlom, K. M. Shen, and J. M. Maxson, “Single-Crystal Alkali Antimonide Photocathodes: High Efficiency in the Ultrathin Limit,” *Phys. Rev. Lett.*, vol. 128, no. 11, p. 114801, Mar. 2022	LASSP LEPP CHEM
W. H. Li, C. J. R. Duncan, M. B. Andorf, A. C. Bartnik, E. Bianco, L. Cultrera, A. Galdi, M. Gordon, M. Kaemingk, C. A. Pennington, L. F. Kourkoutis, I. V. Bazarov, and J. M. Maxson, “A kiloelectron-volt ultrafast electron micro-diffraction apparatus using low emittance semiconductor photocathodes,” *Structural Dynamics*, vol. 9, no. 2, p. 024302, Mar. 2022	LASSP AEP BNL
J. Jarvis, V. Lebedev, A. Romanov, D. Broemmelsiek, K. Carlson, S. Chattopadhyay, A. Dick, D. Edstrom, I. Lobach, S. Nagaitsev, H. Piekarz, P. Piot, J. Ruan, J. Santucci, G. Stancari, and A. Valishev, “First Experimental Demonstration of Optical Stochastic Cooling,” *arXiv:2203.08899 [physics]*, Mar. 2022	FNAL NIU
J. B. Gibson, A. C. Hire, and R. G. Hennig, “Data-Augmentation for Graph Neural Network Learning of the Relaxed Energies of Unrelaxed Structures,” *arXiv:2202.13947 [physics]*, Feb. 2022	Florida
J. N. Nelson, N. J. Schreiber, A. B. Georgescu, B. H. Goodge, B. D. Faeth, C. T. Parzyck, C. Zeledon, L. F. Kourkoutis, A. J. Millis, A. Georges, D. G. Schlom, and K. M. Shen, “Interfacial charge transfer and persistent metallicity of ultrathin $SrIrO_3$/$SrRuO_3$ heterostructures,” *Science Advances*, vol. 8, no. 5, p. eabj0481, Feb. 2022	AEP LASSP
S. Deyo, M. Kelley, N. Sitaraman, T. Oseroff, D. B. Liarte, T. Arias, M. Liepe, and J. P. Sethna, “Dissipation by surface states in superconducting RF cavities,” *arXiv:2201.07747 [cond-mat, physics:physics]*, Jan. 2022	LASSP LEPP
Y. Gao, W. Lin, K. A. Brown, X. Gu, G. H. Hoffstaetter, J. Morris, and S. Seletskiy, “Bayesian optimization experiment for trajectory alignment at the low energy RHIC electron cooling system,” *Phys. Rev. Accel. Beams*, vol. 25, no. 1, p. 014601, Jan. 2022	LEPP BNL
G. Ha, K.-J. Kim, P. Piot, J. G. Power, and Y. Sun, “Bunch Shaping in Electron Linear Accelerators,” *Reviews of Modern Physics*, Oct. 2021	NIU ANL
R. G. Farber, S. A. Willson, and S. J. Sibener, “Role of nanoscale surface defects on Sn adsorption and diffusion behavior on oxidized Nb(100),” *Journal of Vacuum Science & Technology A*, vol. 39, no. 6, p. 063212, Dec. 2021	Chicago
J. Lim, A. C. Hire, Y. Quan, J. S. Kim, S. R. Xie, R. S. Kumar, D. Popov, C. Park, R. J. Hemley, J. J. Hamlin, R. G. Hennig, P. J. Hirschfeld, and G. R. Stewart, “Creating superconductivity in WB2 through pressure-induced metastable planar defects,” *arXiv:2109.11521 [cond-mat]*, Sep. 2021	Florida
A. Scheinker, F. Cropp, S. Paiagua, and D. Filippetto, “An adaptive approach to machine learning for compact particle accelerators,” *Sci Rep*, vol. 11, no. 1, p. 19187, Sep. 2021	LBNL UCLA
J. T. Paul, A. Galdi, C. Parzyck, K. M. Shen, J. Maxson, and R. G. Hennig, “Computational synthesis of substrates by crystal cleavage,” *npj Comput Mater*, vol. 7, no. 1, pp. 1–6, Sep. 2021	Florida LASSP LEPP
C. Zhang, Z. Baraissov, C. Duncan, A. Hanuka, A. Edelen, J. Maxson, and D. Muller, “Aberration Corrector Tuning with Machine-Learning-Based Emittance Measurements and Bayesian Optimization,” *Microscopy and Microanalysis*, vol. 27, no. S1, pp. 810–812, Aug. 2021	LEPP AEP SLAC
D. B. Durham, C. M. Pierce, F. Riminucci, S. R. Loria, K. Kanellopulos, I. Bazarov, J. Maxson, S. Cabrini, A. M. Minor, and D. Filippetto, “Characterizing plasmon-enhanced photoemitters for bright ultrafast electron beams,” in *Plasmonics: Design, Materials, Fabrication, Characterization, and Applications XIX*, Aug. 2021	SLAC LEPP LBNL
O. Chubenko, S. Karkare, D. A. Dimitrov, J. K. Bae, L. Cultrera, I. Bazarov, and A. Afanasev, “Monte Carlo modeling of spin-polarized photoemission from p-doped bulk GaAs,” *Journal of Applied Physics*, vol. 130, no. 6, p. 063101, Aug. 2021	ASU LEPP
J. Lim, A. C. Hire, Y. Quan, J. Kim, L. Fanfarillo, S. R. Xie, R. S. Kumar, C. Park, R. J. Hemley, Y. K. Vohra, R. G. Hennig, P. J. Hirschfeld, G. R. Stewart, and J. J. Hamlin, “High-pressure study of the low-Z rich superconductor Be22Re,” *Phys. Rev. B*, vol. 104, no. 6, p. 064505, Aug. 2021	Florida
T. Y. Posos, O. Chubenko, and S. V. Baryshev, “Confirmation of Transit-Time Limited Field Emission in Advanced Carbon Materials with Fast Pattern Recognition Algorithm,” *arXiv:2108.07440 [physics]*, Aug. 2021	ASU
N. Majernik, G. Andonian, R. Roussel, S. Doran, G. Ha, J. Power, E. Wisniewski, and J. Rosenzweig, “Multileaf Collimator for Real-Time Beam Shaping using Emittance Exchange,” *arXiv:2107.00125 [physics]*, Jun. 2021	UCLA
A. Galdi, J. Balajka, W. J. I. DeBenedetti, L. Cultrera, I. V. Bazarov, M. A. Hines, and J. M. Maxson, “Reduction of surface roughness emittance of Cs3Sb photocathodes grown via codeposition on single crystal substrates,” *Appl. Phys. Lett.*, vol. 118, no. 24, p. 244101	LEPP CHEM BNL
R. Roussel, A. Hanuka, and A. Edelen, “Multiobjective Bayesian optimization for online accelerator tuning,” *Phys. Rev. Accel. Beams*, vol. 24, no. 6, p. 062801, Jun. 2021	Chicago SLAC
J. Mann and J. Rosenzweig, “Semi-Classical Cutoff Energies for Electron Emission and Scattering at Field-Enhancing Nanostructures with Large Ponderomotive Amplitudes,” *arXiv:2105.10601 [cond-mat]*, May 2021	UCLA
S. T. Wang, M. B. Andorf, I. V. Bazarov, W. F. Bergan, V. Khachatryan, J. M. Maxson, and D. L. Rubin, “Simulation of transit-time optical stochastic cooling process in Cornell Electron Storage Ring,” *Phys. Rev. Accel. Beams*, vol. 24, p. 064001, Jun. 2021	LEPP

Team Science

Collab-o-gram



43% of CBB pubs have authors from different institutions or different disciplines

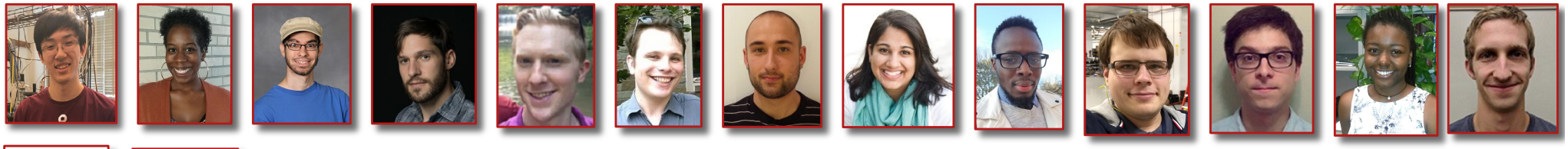
Team Science is key to CBB success

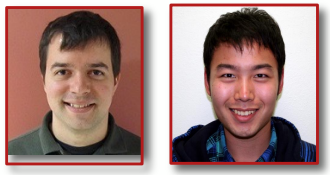
CBB Alumni

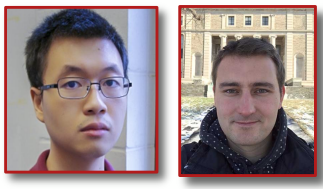
See talk by M. Hines

41 highly-trained scientists by the end of year 5 Interdisciplinary team science, plus training in entrepreneurship, communication, ethics, mentorship, diversity & inclusion....

CBB priority: **Diversity** The Division of the Physics of Beams of the APS has the lowest female representation of all 16 APS units except one (13%)







MS	Maria	
	Brian	
	Eylen	
	Nilanj	
	Alex I	
Ph. D.	Alex Cahill	Varian Medical Systems, Eng. Physicist
	Colin Clement	Microsoft, Data Scientist
	Paul Cueva	Corning, Scientist
	Will DeBenedetti	Pacific Northwest Nat. Lab., Postdoc
	Cameron Duncan	EPFL, Postdoc
	Lipi Gupta	Lawrence Berkeley Nat. Lab, Postdoc
	Matthew Gordon	National Lab, Postdoc
	Daniel Hall	ASML, Sr. Design Engineer
	Frank Ikponmwen	FDA, Analytical Chemist
	Nikita Kuklev	Argonne Nat. Lab., Postdoc
	William Li	Brookhaven Nat. Lab., Postdoc
	James T. Maniscalco	SLAC, SRF Engineer
	Allison McMillan	Interviewing
	J. Kevin Nangoi	UC Santa Barbara, Postdoc
	Alden Pack	Sandia Nat. Lab, Albuquerque, Postdoc
	Joshua Thomas Paul	Argonne Nat. Lab, Postdoc
	Ryan Porter	SLAC, Postdoc

20% URM and 22% female

	Darren Veit	TBD
Postdoc	Matthew Andorf	Cornell U. , Res. Assoc.
	Jan Balajka	TU Wien, Postdoc
	Stanislav Baturin	Northern Illinois U., Asst. Professor
	Oksana Chubenko	Northern Illinois U., Asst. Professor
	Rachael Farber	University of Kansas, Asst. Professor
	Alice Galdi	U. of Salerno, Italy, Assoc. Professor
	Jacob Graham	NASA Goddard, Space Res. Scientist
	Siddharth Karkare	Ariz. State U., Asst. Professor
	Danilo Liarte	Cornell U. , Res. Assoc.
	Andy Linscheid	Tom Tom, Germany
	Jared Maxson	Cornell U., Asst. Professor
	Jorge Giner Navarro	CIEMAT, Madrid, Researcher
	Ryan Roussel	SLAC, Postdoc
	Dulanga Somartne	Unknown
	Chenyu Zhang	ASML, Sr. Software Engineer
RA	Luca Cultrera	Brookhaven Nat. Lab., Scientist

Academia/Education
Industry
Gov't/ National Lab

Inclusion: A core value

Inclusion enables teamwork

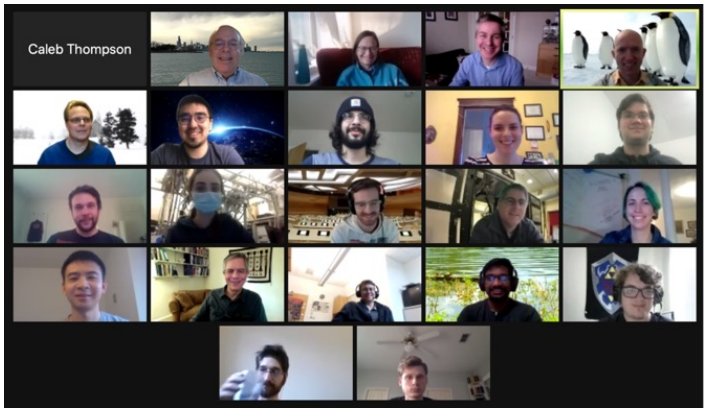
- Weekly newsletter with DE&I resources
- DE&I and mentorship workshops
- Implicit Bias diagnostics for all members
- Zoom best practices for inclusion
- Diversity as part of internal proposals
- Annual climate study by external evaluators

Faculty, postdocs, graduate and undergraduate students

Socially-distanced CBB picnic

A CBB Zoom practice:
Turn on video or show a photo

Examples:



A recent CBB Theme Meeting

At a recent conference
20% of non-CBBers showed a photo
69% of CBBers did so

Sharing your picture makes a meeting more welcoming

Strategic Plan

- Guides CBB activities and budgeting
- Seeks to maximize impact and legacy
- Evolves annually to reflect world accelerator priorities, context, progress, and lessons learned
- Enables the rotation of participants in and out of the center

Center for BRIGHT BEAMS
A National Science Foundation Science & Technology Center

Strategic Plan, 2021-2026

Vision and Mission

Vision

Gain the fundamental understanding needed to transform the brightness of electron beams available to science, medicine, and industry.

Mission

Transform the reach of electron beams by advancing fundamental knowledge and applying it to increase beam brightness x100 and reduce the cost and size of key enabling technologies. Ensure that these new approaches are realized in operating accelerators by transferring the best of them to national labs and industry. Educate and inspire a diverse generation of students to prepare them for a broad set of career paths including leadership in interdisciplinary team science.

CBB's scientific advances are extending the capabilities of the approximately 15,000 U.S. researchers who rely on large particle accelerators to advance the frontiers of physics, chemistry, materials science, biology, and medicine [1]. CBB's research will reduce the cost and improve the performance of small laboratory instruments and industrial tools, as well as large colliders and X-ray sources. CBB will help realize university-scale X-ray FELs capable of femtosecond imaging; ultrafast electron diffraction set-ups that can image not only nanoscale, but also molecular assemblies; and electron microscopes equipped with bright sources that directly investigate phonon-coupling dynamics, opening new pathways for quantum materials [2]. Brighter beams in future electron-ion colliders will unlock the secrets of the "glue" that binds the building blocks of visible matter in the universe; and simpler, cheaper designs may enable an electron-positron collider that glimpses closer to the big bang. CBB will also extend the capabilities of beams available to medicine and industry, which currently operate 30,000 accelerators and add 10 new ones each day [3]. Areas of growth include semiconductor fabrication, metrology, and new green technologies. These advances are CBB's *outcome legacy* and realizing them depends on effective Knowledge Transfer to national labs and industry.

Large-scale colliders, intense X-ray sources, and electron microscopes are essential tools for science and industry, yet the U.S. educates few students to understand the bright electron beams

Center for Bright Beams Strategic Plan 2021-2026

Site Visit Report 2021

The CBB has a comprehensive **strategic plan** that clearly defines the Center's expected legacy. It is a strength that the plan is updated annually with advice from the External Advisory Board (EAB). The strategic plan is appropriately ambitious, with laudable goals and well posed driving questions that feed into the annual internal proposal process. If the objectives are met the CBB will have a strong legacy overall. **The students and young professionals are already a successful legacy, and the knowledge legacy is secure.** **The technical outcome legacy is still to be determined.** **Team science will also be an important part of CBB's legacy.**

Responding to this feedback was one of CBB's two management priorities for 2021-22.

Strategic Plan example

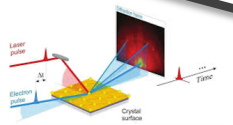
Optimal Outcome

Objectives

BEAM PRODUCTION Roadmap 2022

The understanding, materials, and technology necessary to produce the brightest possible electron beams across the wide span of beam currents, pulse durations, and operating environments demanded by forefront scientific research and emerging technological applications.

FY 22 | FY 23 | FY 24 | FY 25 | FY 26

Objectives	Deliverables	Legacy
Develop photocathodes for high peak-intensity beam generation with <5 meV MTE	20 meV MTE photocathode at operational laser fluences 5 meV MTE photocathode at operational fluences by enhancing QE of ordered III-V and alkali antimonide photocathodes or other single crystals at threshold	 Free Electron Lasers like LCLS2 at SLAC that lase at markedly higher photon energies.
Design materials for long-lived cathodes in extreme electric field and high average current	Robust protective coatings or new materials that extend photocathode lifetimes with little degradation in either QE or MTE	 Extreme, high currents for future particle colliders and x-ray sources.
Approach fundamental brightness limits with nanostructure photoemitters	An electron source with normalized transverse emittance approaching the fundamental limit of 0.2pm Picometer emittances for higher charge per bunch	 Unprecedented resolutions in ultrafast electron diffraction and microscopy to reveal new transient phenomena in materials.

Deliverables with due dates.

Some are due annually.

New

Priority Deliverables

Legacy: an example application

Priority Deliverables

Priority Deliverable features:

- Potential for significant impact and legacy
- Plausibly achievable
- Highest priority for delivery by 2026

CBB may curtail other activities in the future in order to deliver these.

Priority Deliverables get special attention in the Strategic Plan:

- Identified end user
- Plan for accomplishment
- Risk mitigation plan
- Knowledge Transfer plan

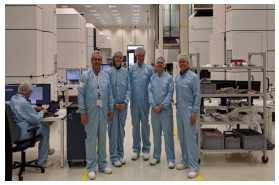
To ensure delivery and clarify the development arc from tech creation to adoption

Old Knowledge Transfer plan

KNOWLEDGE TRANSFER Roadmap

Frequent communication with CBB partners at national laboratories and in industry to promote the transfer of technology and prepare graduate students for productive careers in these sectors.

FY 22 FY 23 FY 24 FY 25 FY 26

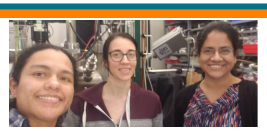
Objectives	Deliverables	Impact
CBB discoveries and designs are incorporated into a new generation of accelerators and commercialized as products	**CBB advances are incorporated into at least two accelerators or their applications**	 **Visit to FEI production clean room for testing high-brightness technologies.**
Trained graduate students are capable of recognizing and transferring critical skills to industry and national lab partners	**40 trained graduate students who are able to transfer their skills to industry and national lab partners**	 **CBB graduate students present their research at conferences.**

Knowledge Transfer 2022

KNOWLEDGE TRANSFER Roadmap 2022

Frequent communication with CBB partners at national laboratories and in industry to promote the transfer of technology and prepare graduate students for productive careers in these sectors.

FY 22 FY 23 FY 24 FY 25 FY 26

Objectives	Deliverables	Impact
CBB shares its knowledge with accelerator scientists and related disciplines	CBB knowledge shared through journal articles, conference proceeding articles, presentations, data sets, technical drawings and other media. Strong engagement with the accelerator and end use communities through conference organization, community service, and research collaboration.	 CBB graduate students present their research at conferences.
CBB discoveries and designs are incorporated into a new generation of accelerators and commercialized as products	Transfer of photocathode with MTE < 35 meV & QE $> 10^{-3}$ at high laser fluence Transfer of robust photocathode with MTE < 35 meV at high laser fluence and high field Transfer of robust photocathode with MTE <100 meV and QE>1% at high average current Transfer of a photoemission source with sub-100 nm spot size. Transfer of non-Nb, high efficiency or high field surfaces Transfer of ML techniques for tuning the higher-order aberrations in electron microscopes Incorporation of other discoveries into new accelerators or commercialization as products	 Visit to FEI production clean room for testing high-brightness technologies.
Trained graduate students bring critical skills to industry & labs	55 trained graduate students who are able to transfer their skills to industry and national lab partners	 A new generation of scientists

KT Example

Deliverable 2.1: The transfer of CBB methods for preparing a photocathode with MTE < 35 meV and QE > 10^{-3} at laser fluences in excess of 50 μJ/cm² (*PHC Deliverable 1.2*).

Plan: This photocathode is aimed at the needs of the LCLS-II-HE SRF gun and electron microscopes. The LCLS-II-HE gun will deliver <100 μA beam current and, as an SRF gun, is expected to have good vacuum conditions. Past demonstrations indicate that MTE of 35 meV would be preserved in the LCLS-II-HE gun for the timescale of a day or more. CBB scientists (Karkare, Maxson, Musumeci) have submitted a joint proposal with scientists from SLAC (Dunham, Lewellen, Vecchione) and LBNL (Filippetto) that would enable tests in Pegasus and at LBNL at high field and at low field in guns at Cornell and ASU. IDES/JEOL has also expressed interest in implementing such a photocathode in one of its electron microscopes. CBB scientists (Karkare, Maxson) and Bryan Reed of JEOL are exploring funding opportunities to build and test a photocathode gun for a JEOL microscope. If successful, CBB would seek industry funding for further development.

Features:

- Identfies contacts
- Specifies current collaborations
- Outlines future steps

Note: This joint proposal has since been funded.

Strategic Plan Update Process

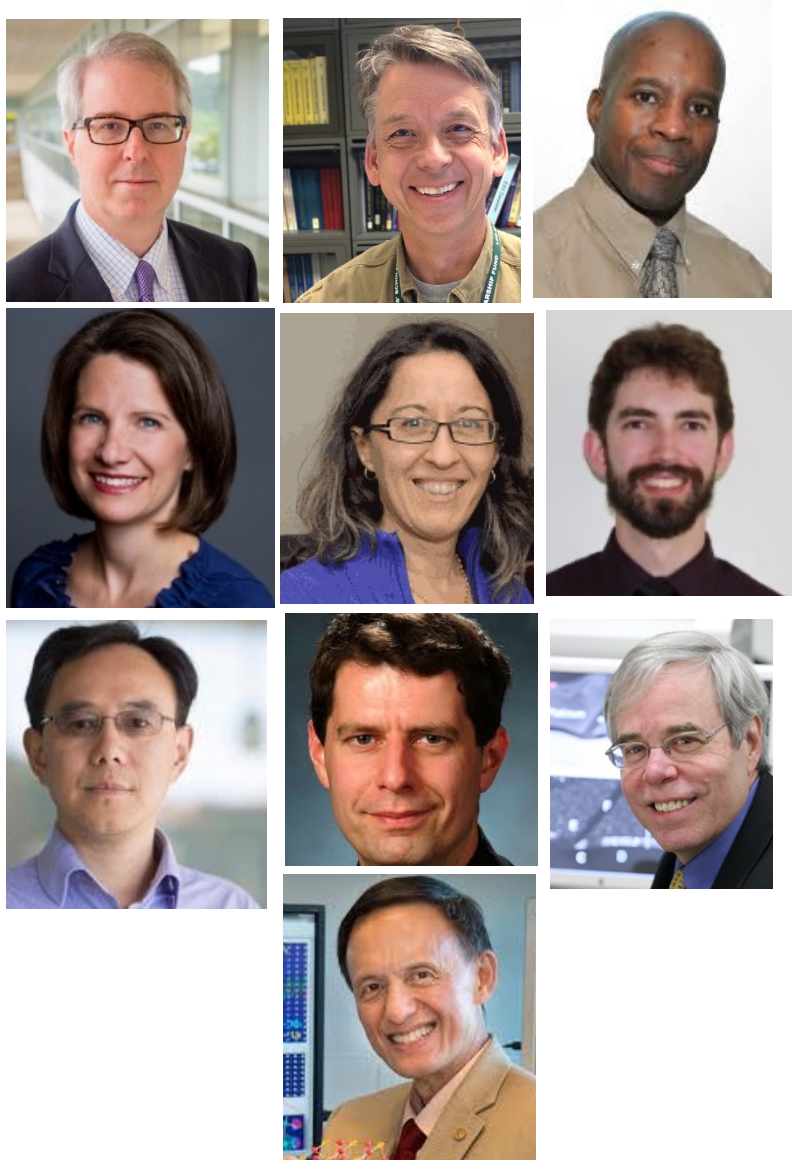
2022

January	February	March
CBB team discusses goals	Theme leaders present drafts to all senior investigators for discussion	

April	May	June
External Advisory Board gives feedback at an in-person review in Chicago	Revisions in response to EAB feedback	Senior Investigators ratify the Strategic Plan and plan projects for the coming year at the annual meeting at UCLA

External Advisory Board

Stuart Henderson (ch.)	Jefferson Lab
Bruce Carlsten	Los Alamos Nat'l Lab
Paul Gueye	Michigan State U.
Kara Hall	National Cancer Institute
Kathy Harkay	Argonne Nat'l Lab
Erik Hosler	PsiQuantum, Inc.
Zhirong Huang	SLAC
Bryan Reed	Integrated Dynamic Electron Solutions/JEOL
Peter Voorhees	Northwestern U.
Yimei Zhu	Brookhaven Nat'l Lab



Strong lab representation, consistent with NSF guidance.

EAB Charge

- Will completion of the “must-do” items result in a significant CBB legacy? Has CBB prioritized adequately? Are there additional high impact legacy items that should be included?

- Are deliverable dates suitable, and where the dates have been changed, is the change justified?

- Are deliverables sufficiently focused and well-chosen?

Full-day in-person meeting with EAB on April 5, 2022

Outcome:

- Endorsement of the deliverables and prioritization
- Eagerness for demonstration of 100 nC, 100 pm
- Encouragement to “complete the arc” from tech invention to application → **Resulted in a major rewrite of the KT plan**

CBB budget allocation

Strategic Plan guides budgeting

- CBB research consists of a **package of projects**, which are developed and funded annually.
- Each project supports one student or postdoc and addresses a **specific deliverable** in the Strategic Plan.
- Funding is open to anyone and is our mechanism for welcoming new members.
  Examples:
  Sandra Biedron (UNM) 2020
  Oksana Chubenko (NIU) 2022

Project development and selection:

Faculty talk through project ideas for the coming year at a full day meeting.

Faculty then submit brief, written proposals for their project(s)

Given the prior discussion and vetting, the vast majority of projects are aligned with the Strategic Plan and well-planned, and are awarded funding.

Upshot

CBB provides stable support for students and postdocs, while delivering a research program that is coordinated and dynamic.

New Faculty Member

Oksana Chubenko
Assistant Professor, Northern Illinois

Previously: CBB postdoc at Arizona State

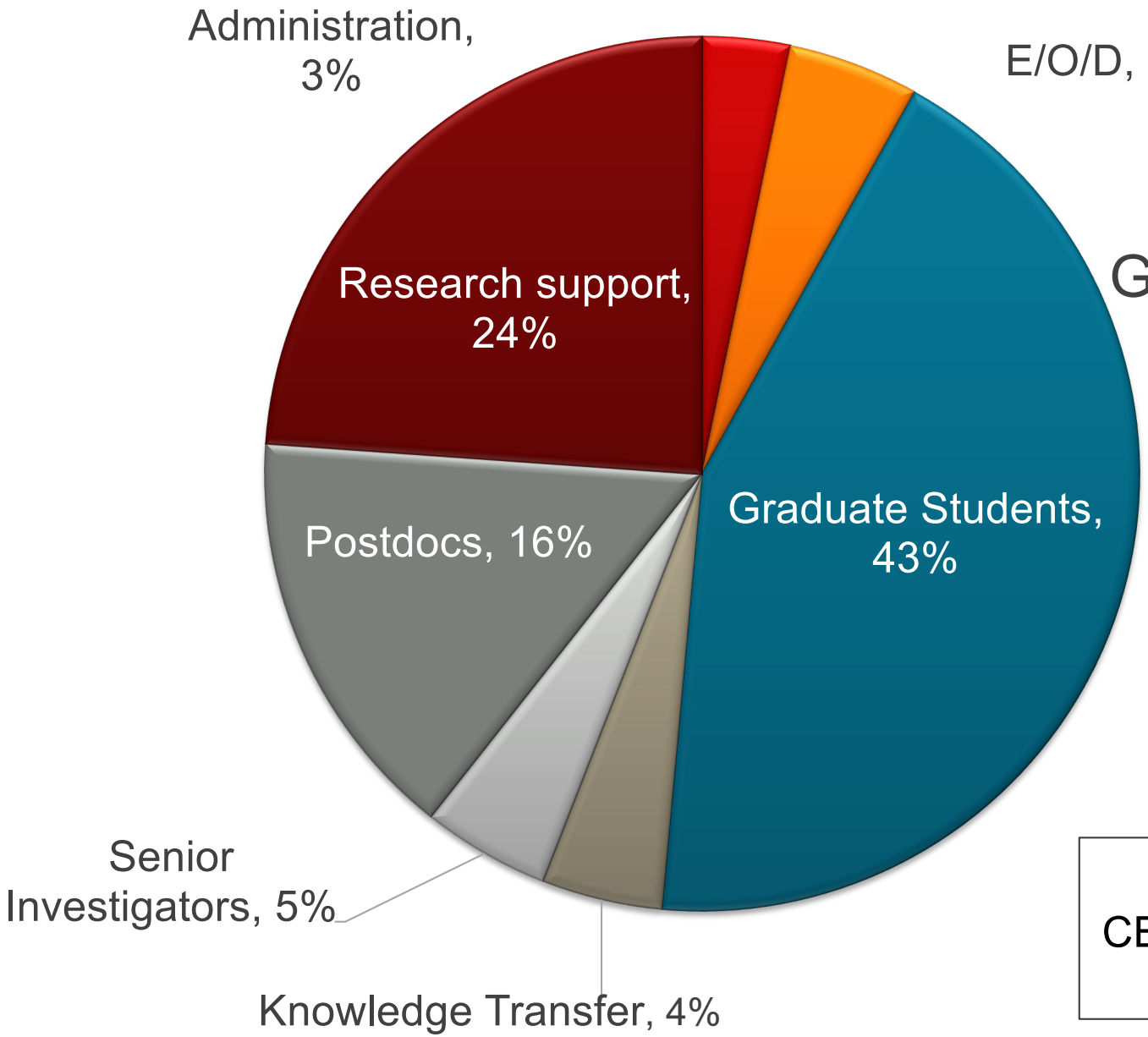
Prof. Chubenko's projects:

Monte Carlo modeling
of photoemission from semiconductors

Photocathodes
under realistic accelerator conditions

Welcome, Oksana!

CBB Budget Allocation Year 6

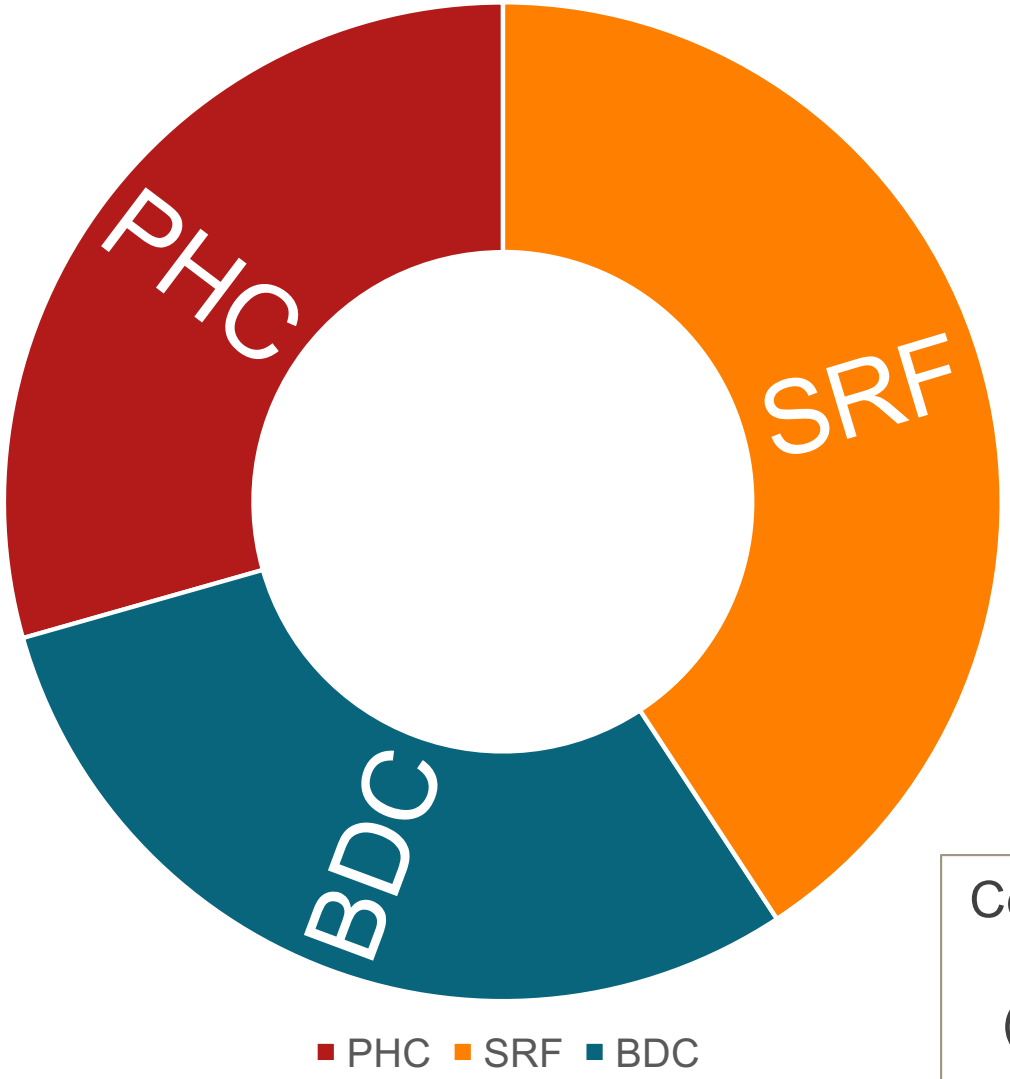


Grand total $5.62M
(incl. F&A)

Fractions exclude F&A

Shared facilities
CBB manages no shared facilities.

Allocation by Theme

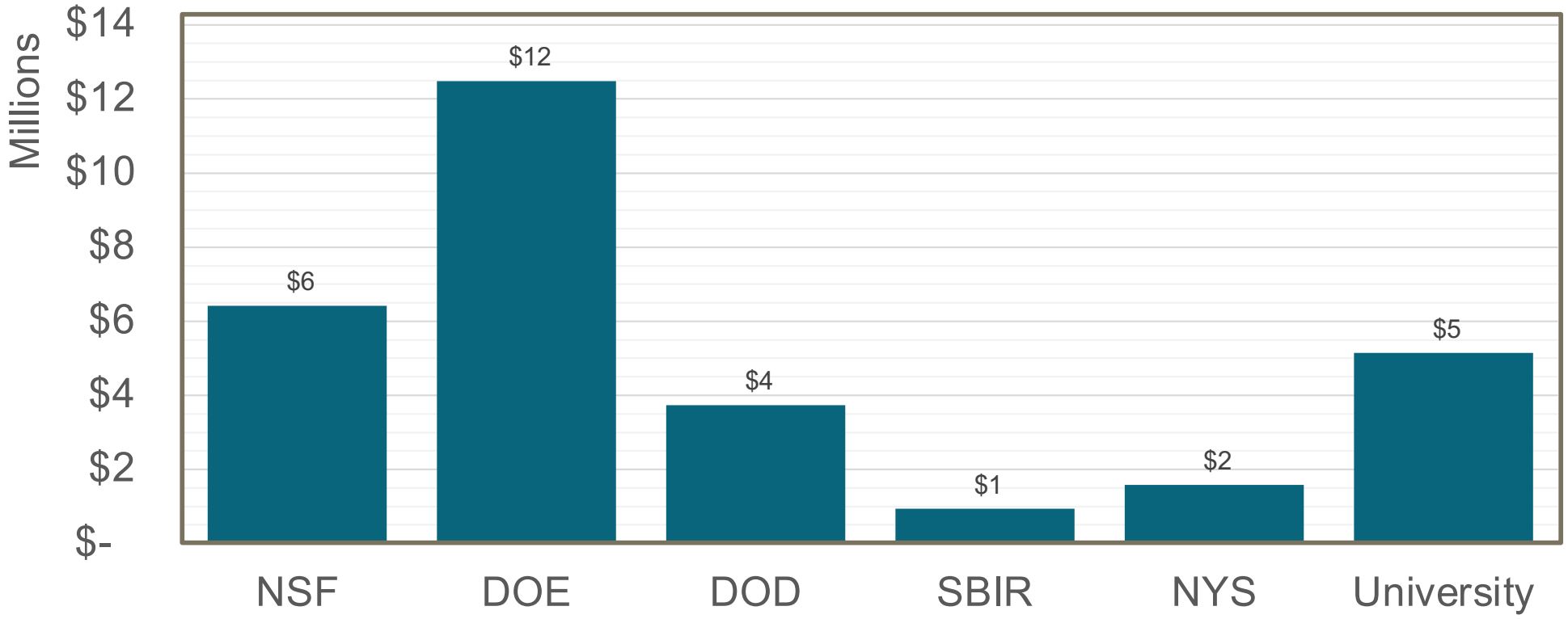


Each theme has ~15 grad students

This split is the result of bottoms up planning and the proposal process.

Cornell accounts for about ½ of CBB by any metric (leadership, meeting host, students, etc.)

Leveraged Funding Years 1 - 6



euclid TECHLABS

STAR CRYOELECTRONICS

ULTRAMET ADVANCED MATERIALS SOLUTIONS

NIOWAVE

TECH

NSF

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

DARPA

NEW YORK STATE OF OPPORTUNITY. Division of Science, Technology & Innovation

ASU ARIZONA STATE UNIVERSITY

CORNELL UNIVERSITY FOUNDED A.D. 1865

Cornell University

Safety

CBB takes safety seriously: all funded CBB participants must be up to date on safety trainings and abide by local rules.

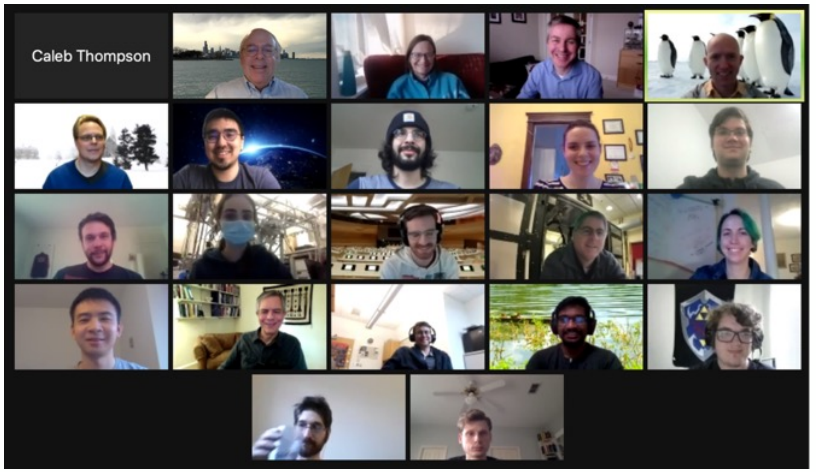
Local safety authorities:

- Arizona State U: https://cfo.asu.edu/research-teaching-labs
- Berkeley Lab: https://ehs.berkeley.edu/laboratory-safety-manual
- Brigham Young U: https://lifesciences.byu.edu/safety
- Cornell: https://sp.ehs.cornell.edu/lab-research-safety/Pages/default.aspx and https://wiki.classe.cornell.edu/Safety/Handbook/ .
- University of Chicago: https://researchsafety.uchicago.edu
- University of Florida: http://www.ehs.ufl.edu/programs/lab/
- Fermilab: https://eshq.fnal.gov/
- UC Los Angeles: https://cls.ucla.edu/
- Northern Illinois University: https://www.niu.edu/divresearch/compliance/safety/index.shtml
- SLAC https://www-group.slac.stanford.edu/esh/

COVID-19 impact

Practial Impact

- **Slowed lab research and training**, in spite of strategies such as staggering shifts, podding, smart use of time outside the lab
- **Equipment delays**, eg *7-month delay* for stainless steel parts for ASU vacuum gun
- **Conference and workshop postponements; eliminated proceedings.**
  In accelerator physics, these are a primary means for communicating results.



As a distributed center, CBB has always relied on Zoom.

CBB complied fully with federal, state, local and institutional guidelines.

Team Integration:

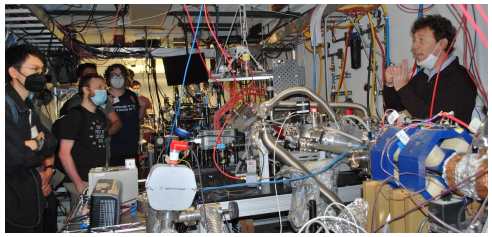
- New students and postdocs struggle to integrate in the absence of face-to-face meetings and socializing.

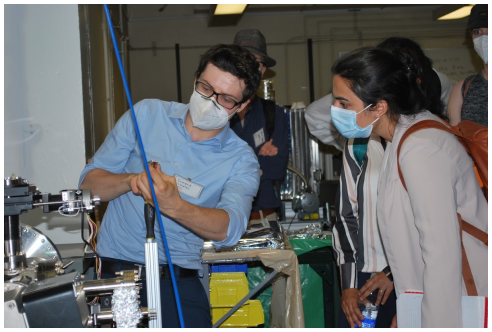
Face-to-face team-building was our second management priority for 2021-22.

CBB at UCLA

In person meeting!!

June 1-3, 2022





CBB at UCLA

Celebrating delivered Deliverables

CBB Legacy

Convergence Research

New paradigm in which accelerator science is highly integrated with condensed matter physics, materials science and surface science.

Knowledge

New understanding of the fundamental limits of photoemission, superconductivity in extreme conditions, and beam dynamics and control.

Technology

Imaging at the atomic scale with unprecedented spatial and temporal resolution, better performing electron microscopes, expanded X-ray energy range from LCLS-II-HE, extended scientific reach for colliders, and **a beam in every basement.**

Delivery has begun.

CBB Legacy (cont.)

Workforce

Prepared for successful careers in an area of critical need.

NSF INCLUDES **NSF Big Idea**

Team Science

Best practices for transdisciplinary team science in the physical sciences.

Growing Convergence Research **NSF Big Idea**

Gaining the fundamental understanding needed to transform the brightness of electron beams available to science, medicine and industry.

Questions?

Data management and IP

Data Management Plan

Goals:

1. Foster free and open internal collaboration (see IPA)
2. Share knowledge gained with the community
3. Ensure that CBB methods are put to use in operating accelerators.

Data Management Plan available on the SV website

Intellectual Property Agreement (IPA)

The CBB IPA assigns IP ownership to the institution of its creator. Results and ideas may be shared externally only by their creator or with the creator's explicit permission.