SLAC Overview

European Laboratory Directors Group Meeting

John Schmerge

June 6, 2024

SLAC NATIONAL ACCELERATOR LABORATORY

Stanford University | U.S. DEPARTMENT OF ENERGY

Outline

SLAC Summary

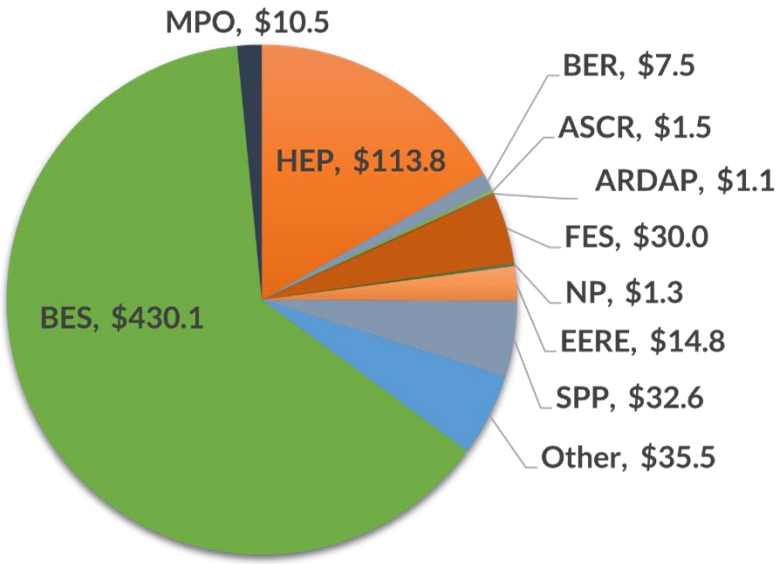
Major Projects

SLAC Science/R&D

Today, SLAC is a vibrant, multi-program laboratory

FY24 forecasted costs by funding source

Total $679M



We are ~$200M bigger than we were in FY20

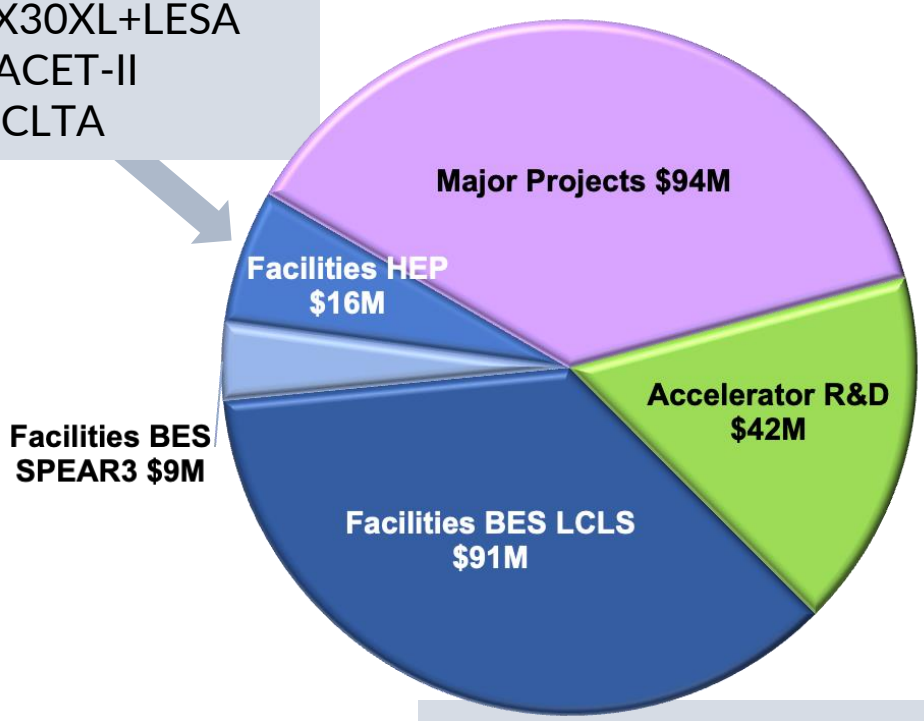
FY23 headcount:

- **1,784** Full-time Employees
- **960** Facility Users
- **46** Faculty; 16 Joint
- **181** Postdocs
- **272** Grad Students
- **53** Undergrads

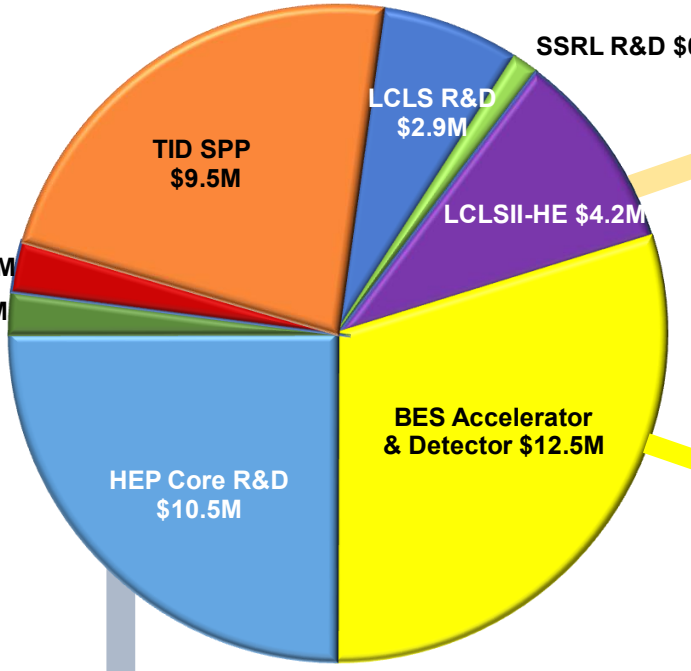
SLAC Accelerator R&D Portfolio

FY23 Accelerator Portfolio
BV: $252M

HEP facilities
- SX30XL+LESA
- FACET-II
- NCLTA



FY23 Accelerator R&D
BV: $42M



High brightness SRF gun
- 2MeV, 100pC, 0.1um emittance at 1MHz
- Prototype development by MSU

Beam technique and SCU
- Ultrafast capabilities
- Cavity based X-FEL
- Superconducting Undulator
- ML based beam diagnostics and accelerator optimization
- Cathode R&D

HEP General Accelerator Research and Development (GARD)
- Beam driven PWFA research
- Accelerator Beam Physics
- ML based beam diagnostics and accelerator optimization
- Advanced RF technology R&D

Recent Challenges

- A serious accident in December 2022
- Accident investigation & launch of Institutional Improvement Plan
- Ongoing focus on disciplined operations and safety culture
- 3 site wide power outages within 12 months seriously disrupting accelerator operations and delaying projects
- Although the LCLS-II Project was completed, we see the first sign of SC cavity field emission increasing

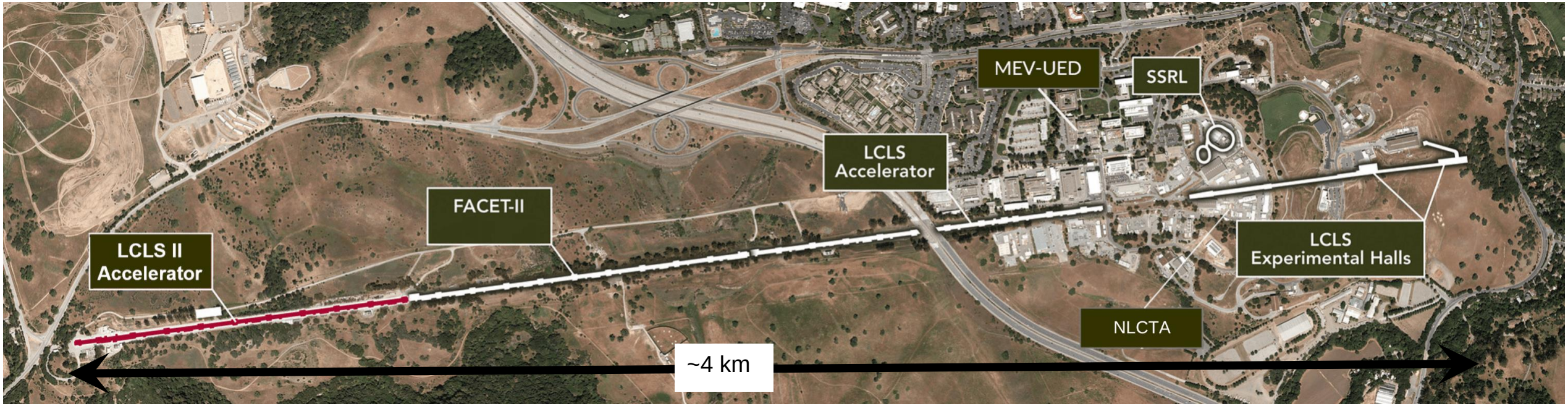
Three Lab Directors

Chi-Chang Kao
Lab Director 2012-2023

Stephen Streiffer
Interim Lab Director 2023

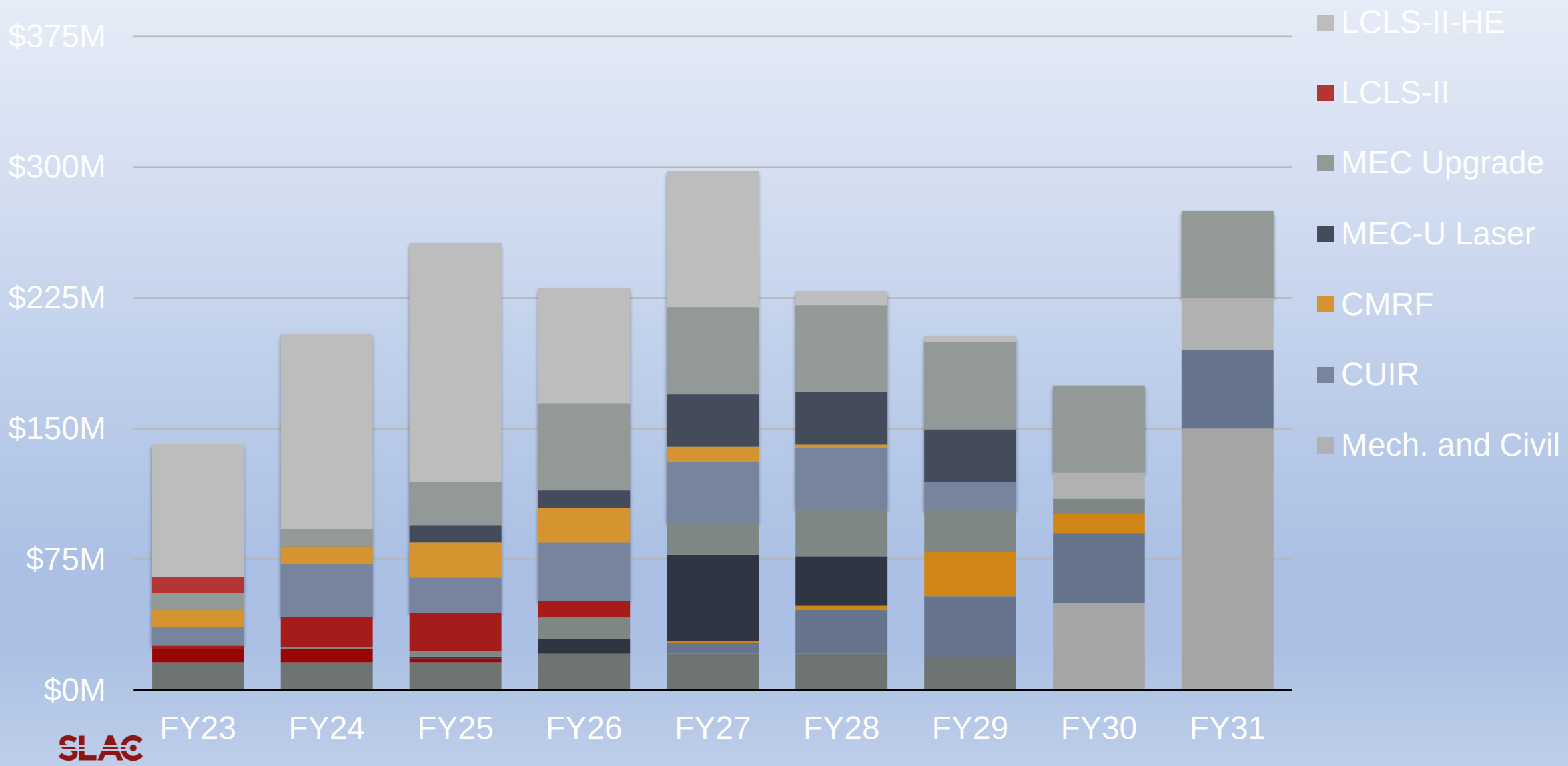
Jahn Sarrao
Lab Director 2023

SLAC Accelerators



- Four DOE User Facilities
  - MeV-UED – 6 MeV
  - SSRL – 3 GeV
  - LCLS - > 4 GeV
  - FACET-II – 10 GeV
- SLAC test facility
  - NLCTA - <10 MeV – 200 MeV

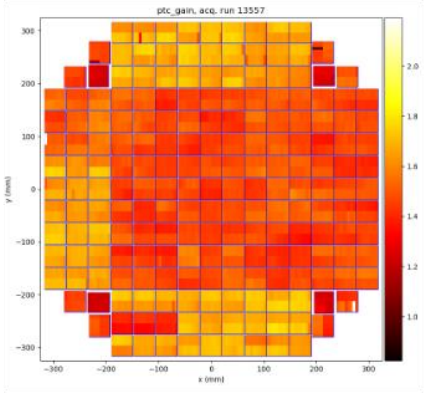
SLAC Major Projects portfolio



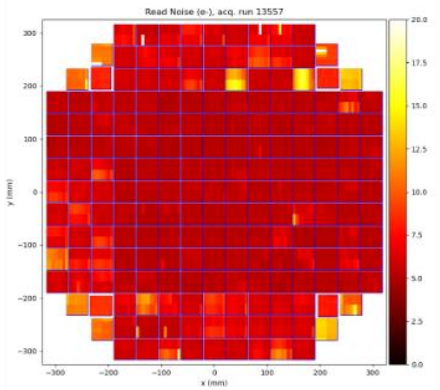
A few highlight of major progress

The LSST Camera has arrived in Chile! The Rubin Observatory is expecting its first light soon!

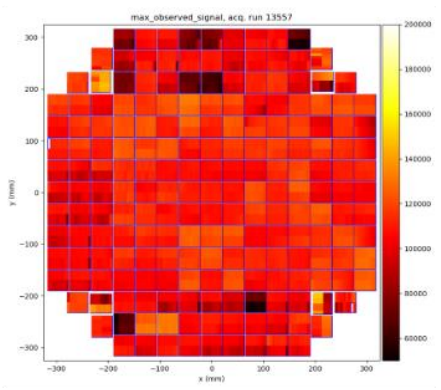
Results from Nov 2023 Electro-Optical Testing



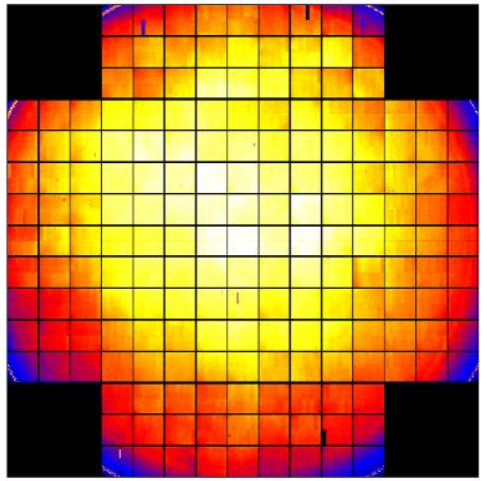
PTC Gain [e-/ADU]



Read Noise [e-]



Full Well [e-]

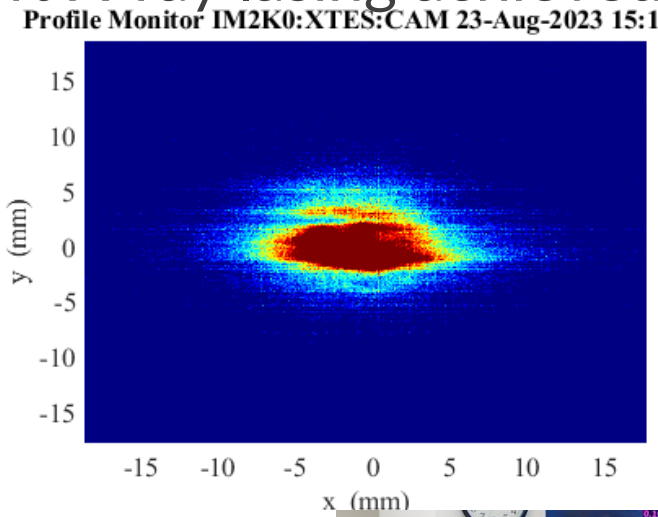


Gain and Q.E. corrected, Flat Image

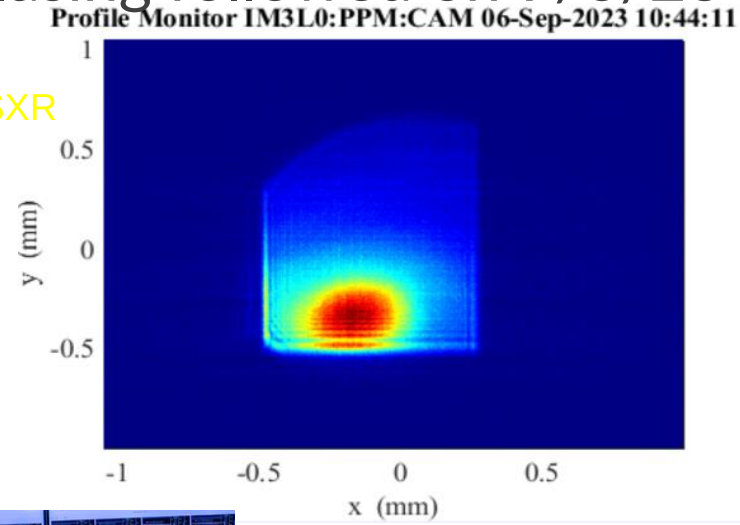
SLAC

LCLS-II has Lased and Transitioned to Operations

Soft X-ray lasing achieved on 8/23/23



Hard X-ray lasing followed on 9/6/23



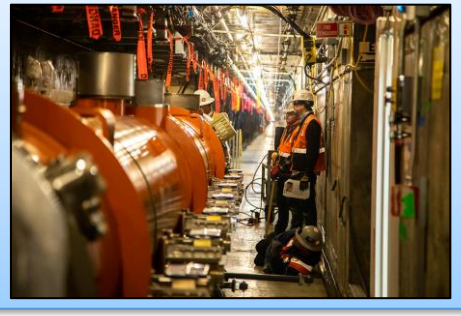
Transition to Operations on Sept. 12

[Press release about LCLS-II first light]

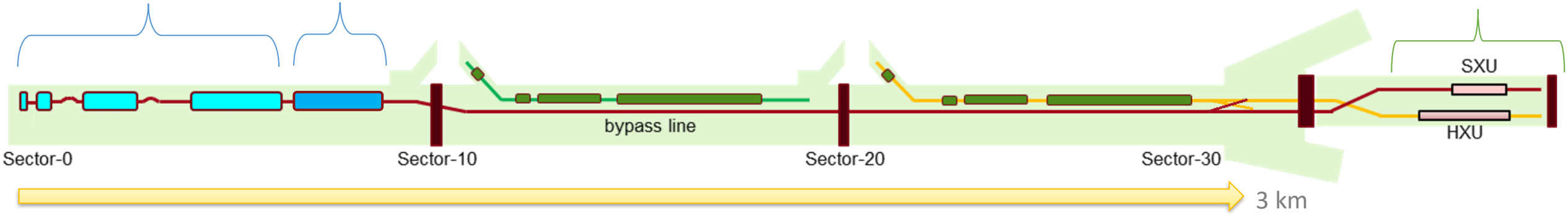
LCLS FEL complex based on normal and superconducting Accelerators

Superconducting Linac
4 GeV, High rep-rate, CW RF

Future 8 GeV extension (LCLS-II-HE)

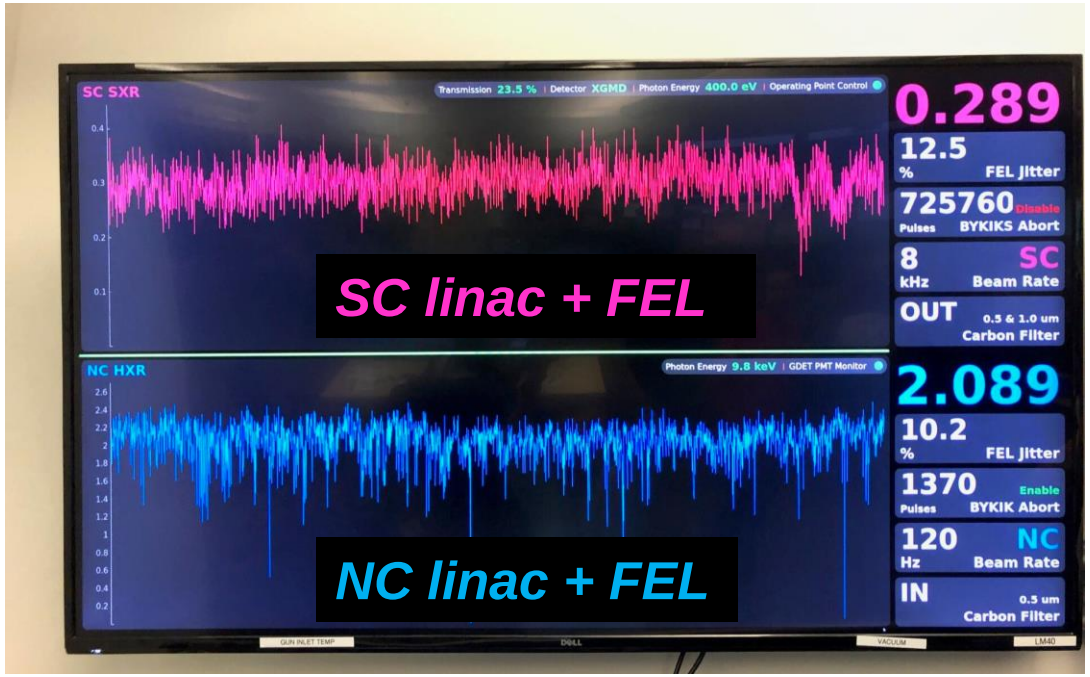


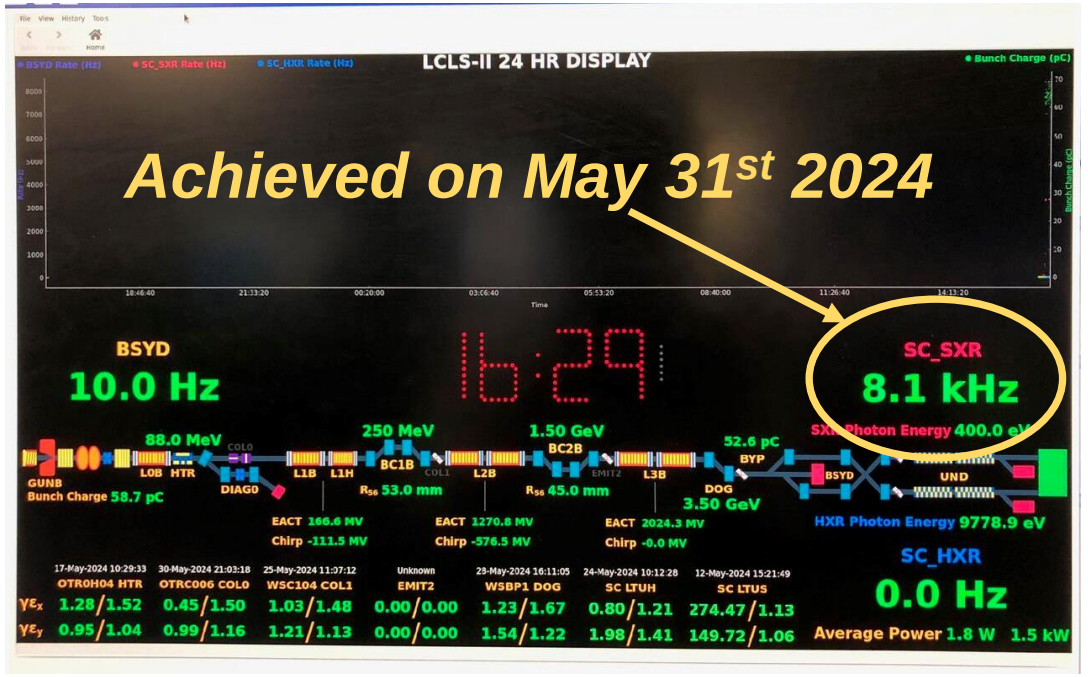
Soft and Hard X-ray Variable Gap Undulators (VGUs)



Normal Conducting Linac
3.5-17 GeV,
120 Hz Pulsed RF

Simultaneous operation of NC and SC based beams





NC linac and FEL delivers beams to users

- Currently operating in Run 22 with excellent performance
- Maintaining and developing advanced capabilities = e.g. seeding, multi-bunches and attosecond pulses

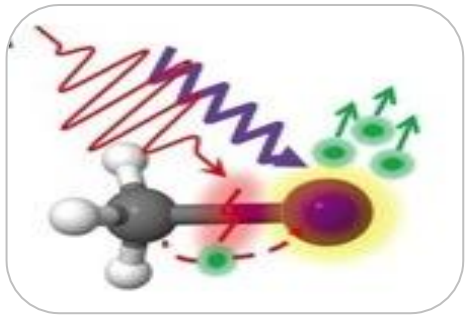
SC linac and FEL achieved kHz Repetiton Rates

- Continuing commissioning and ramp up of rate and beam power (50 pC, 8 kHz, 3.5 GeV, 1.4 kW)
- Delivery of SC based x-ray beam to x-ray hutches for Instrument commissioning and users.

LCLS-II Science will be Transformational

Seeing how physics drives chemistry

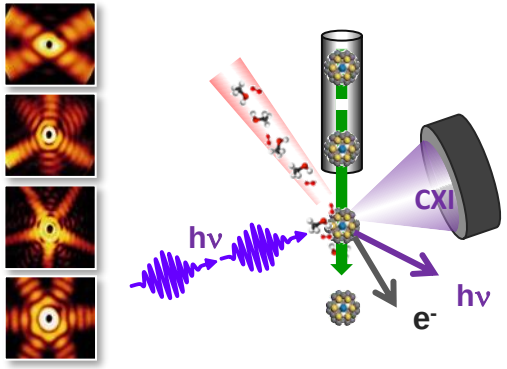
- Reveal coupled electronic and nuclear motion in molecules
- Capture the initiating events of charge transfer chemistry with sub-fs resolution



Ultrafast

How to accelerate chemical reactions

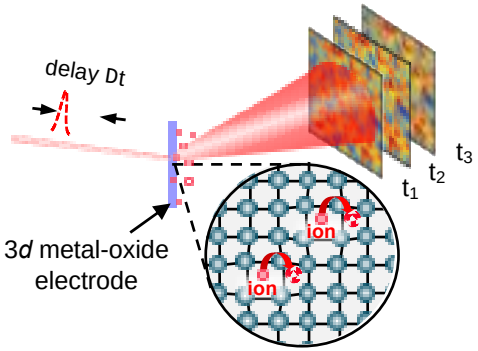
- Correlate catalytic reactivity and structure
- Real-time evolution with chemical specificity and atomic resolution



High repetition rate

Understanding material function and failure

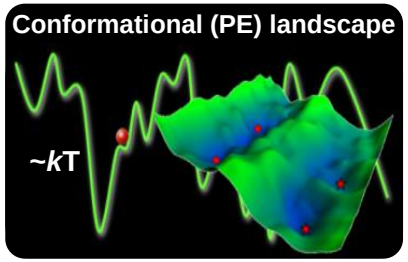
- Characterize dynamic systems without long-range order
- Directed design of energy conversion and storage materials



Coherence

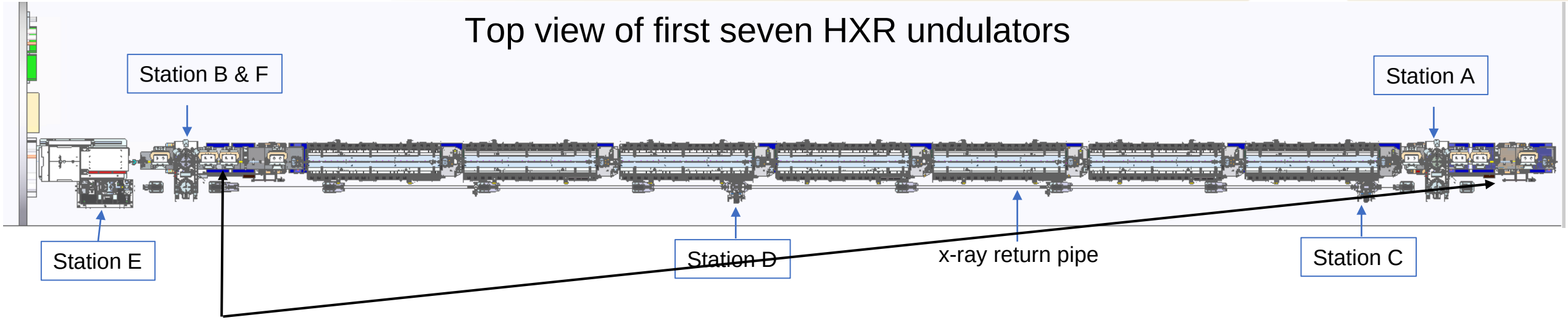
Watching biology in action

- Study large scale conformational changes via solution scattering
- Physiological conditions
- Dynamics ties structure to function



Extreme brightness

CBXFEL project – *ANL/SLAC/Spring-8 collaboration*



Chicanes to by-pass optics (including relocating undulators)

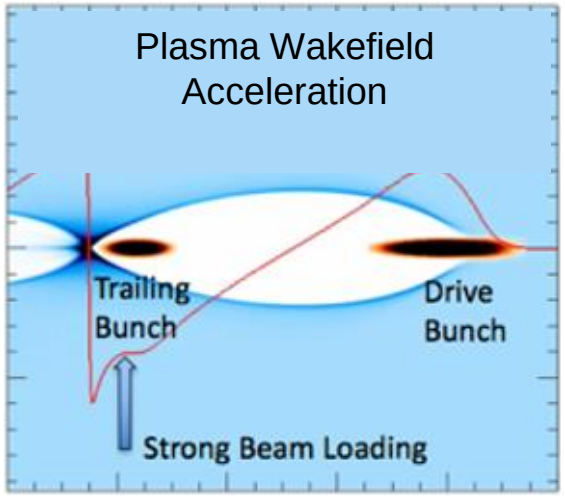
Stations A/B house 4-diamond crystals (including nanopositioning stages)

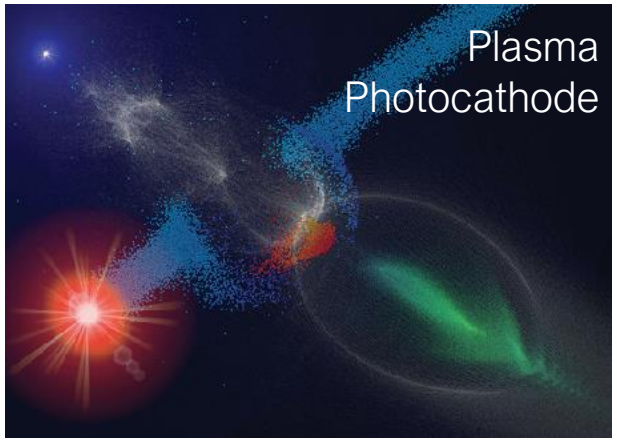
X-ray optics/diagnostics inside stations A/B/C/D/E/F

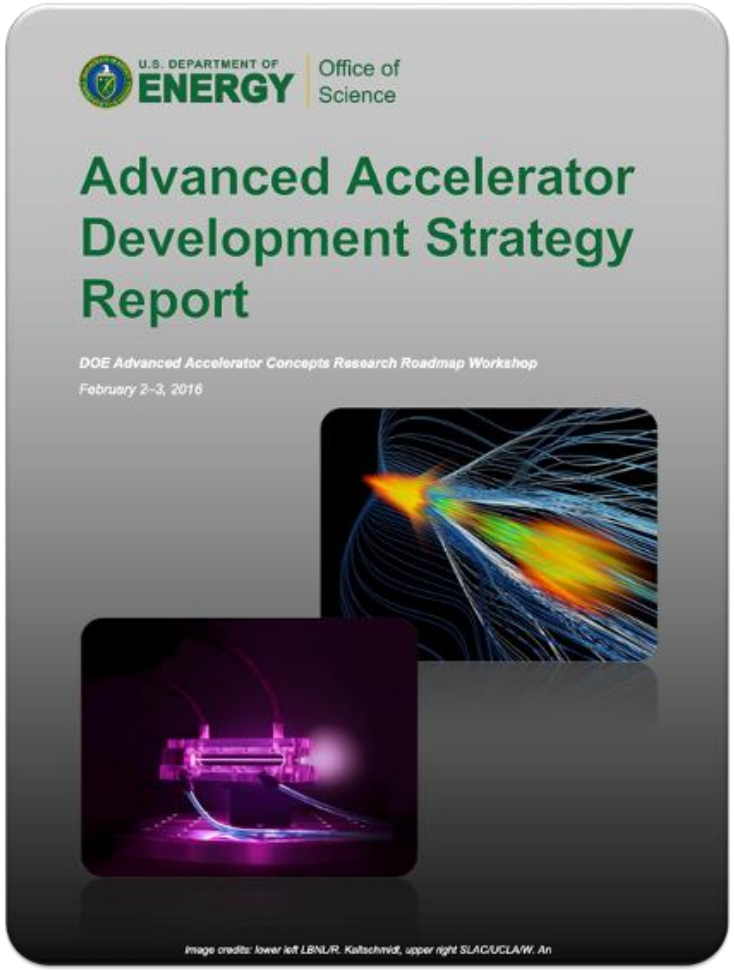
- **Double bunches from the SLAC Cu RF linac** with 624 bucket separation (218.4 ns).
- **Photon energy 9.831 keV. Diamond (400) at 45 degree. Cavity length 65.500873 m**
- Initial performance goals: **measure 2nd pass gain and quantify cavity loss**.
- Characterize cavity stability and tolerances for XRAFEL/XFELO.

FACET-II: Plasma Wakefield R&D

- Initial focus on beam quality in **plasma wakefield accelerators** and generating beams with unprecedented brightness in **plasma based injectors**
- Additional programs will exploit unprecedented beam intensity to create bright **gamma-ray bursts** and study **SFQED** phenomena
- Creating **ML/AI** based virtual diagnostics to characterize extreme beams





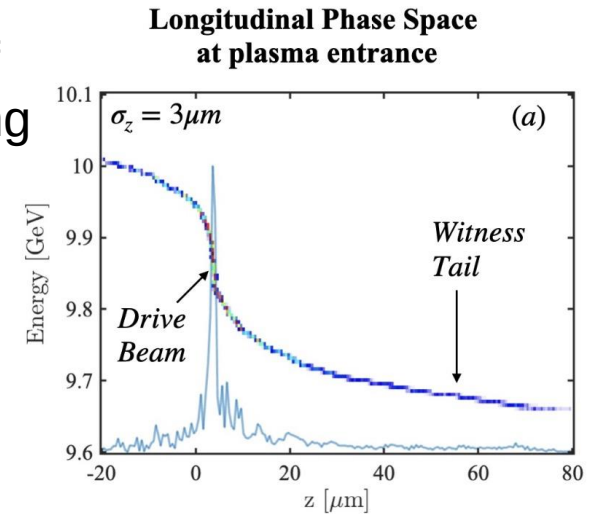


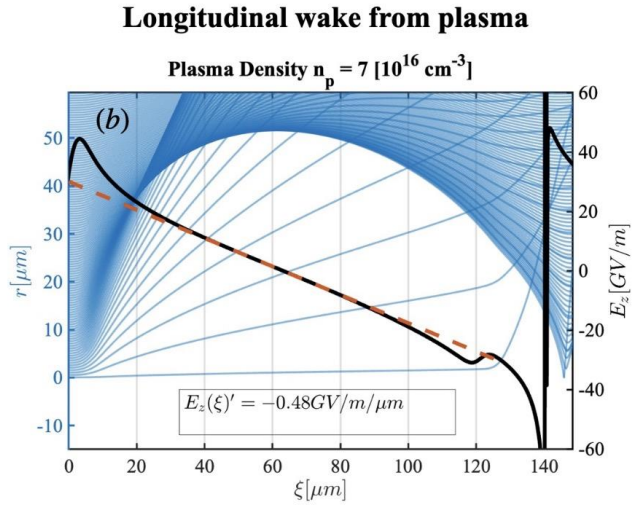
National User Facility based on a 10 GeV beam and their interaction with Lasers and Plasmas

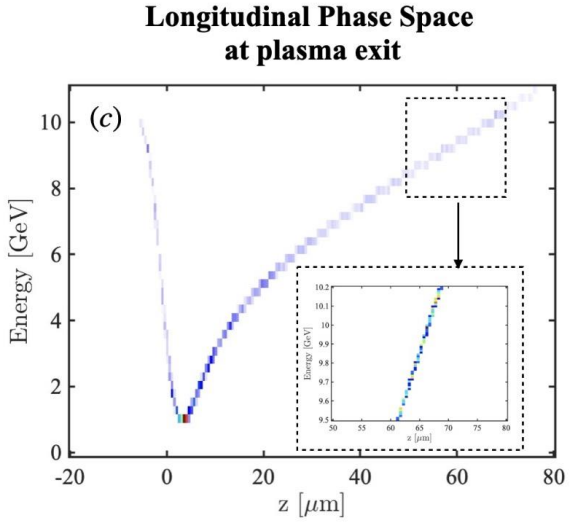
SLAC

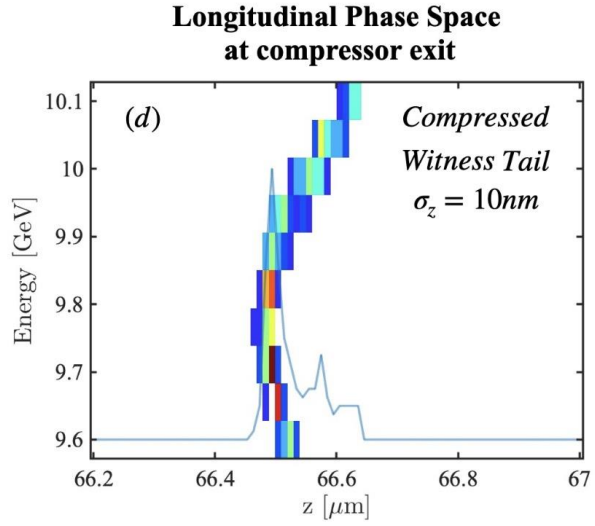
Generating extreme beams using PWFA at FACET-II

- Electron drive beam from FACET-II photoinjector of μm-scale bunch length enters plasma exciting strong wake
- Witness tail experiences linear chirp ~ 1%/μm (1000x larger than FACET-II linac)
- Witness tail is compressed in weak downstream chicane to ~10nm bunch length
- This Early Career Research Program will carry out experiments to explore compressing distinct witness bunches and varying charge, energy, bunch length for different applications

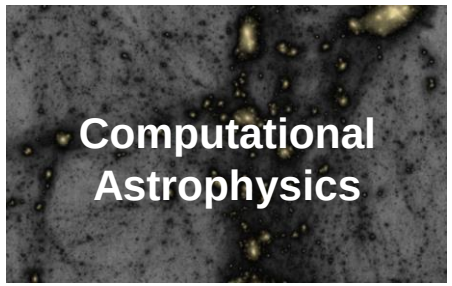


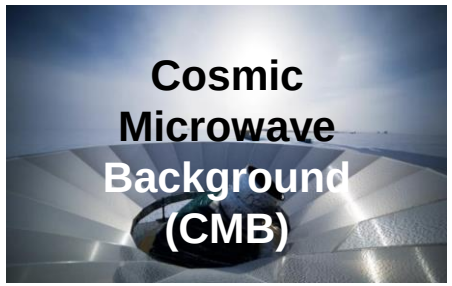


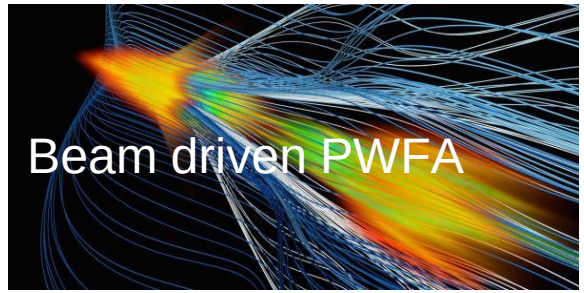


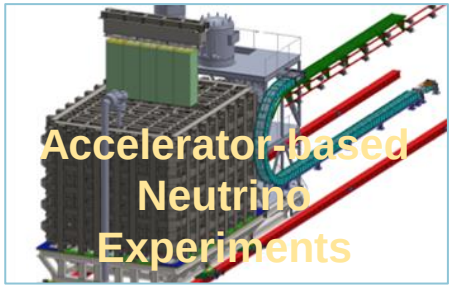


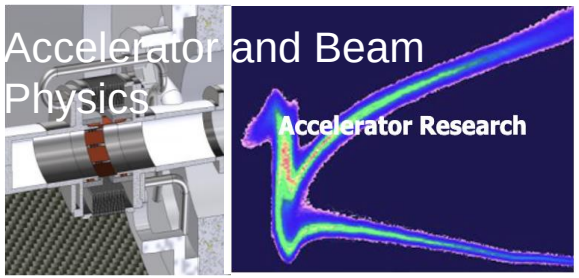
SLAC has broad HEP Programs

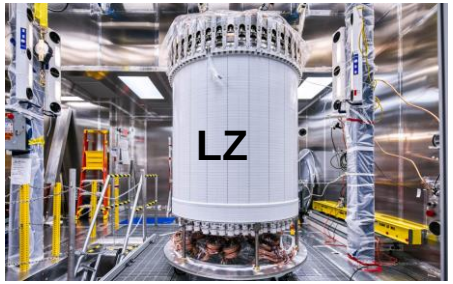


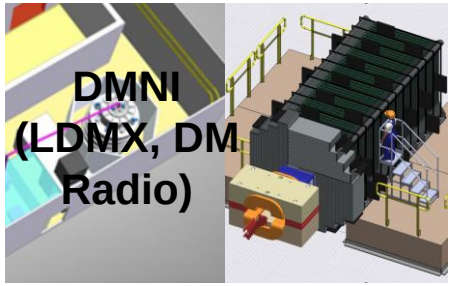


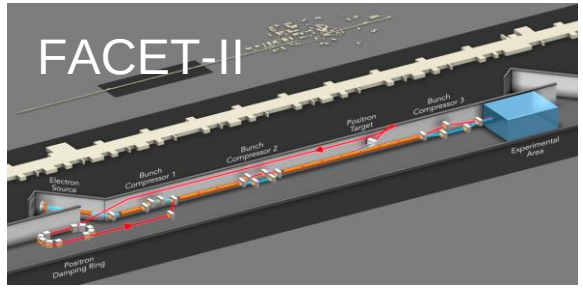


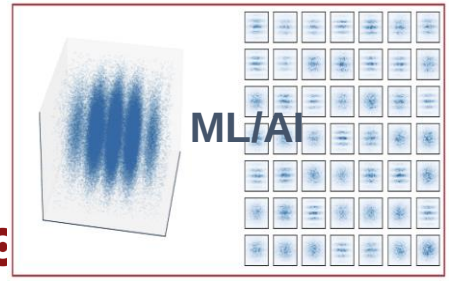


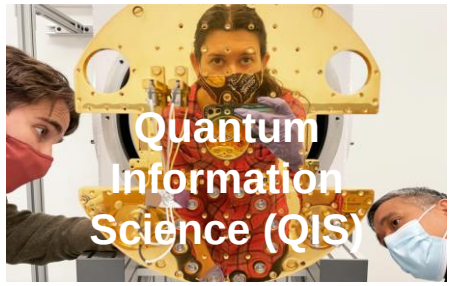


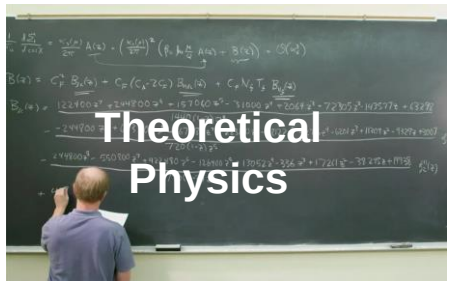


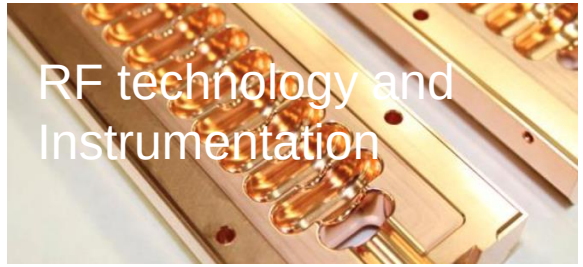












LESA Science: 5-10 year program with 3 Prongs

Sector 30 Transfer Line:

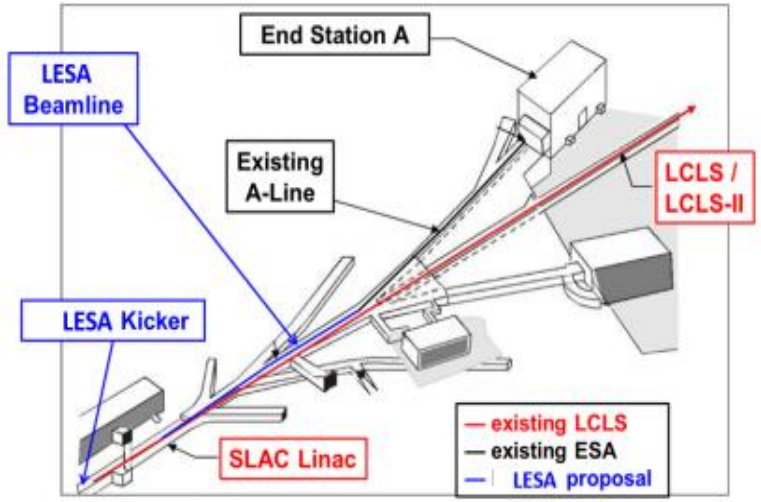
Community Statement of Science and Support

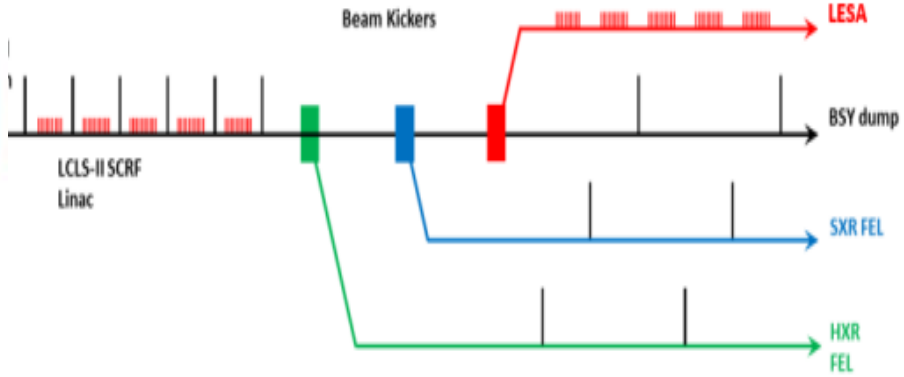
2019 summary of science program, with 18 user statements of interest

Short bunch + high repetition rate test beams

Electron inelastic scattering data for Neutrinos

Light Dark Matter eXperiment (LDMX)

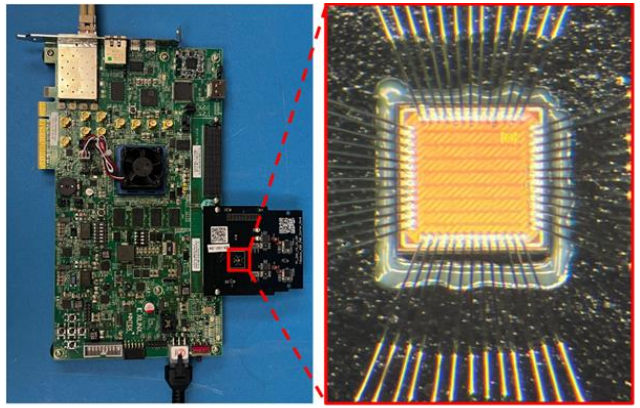




Detector R&D, ML & Microelectronics Highlights over the last ~12 months

Programmable logic on ASIC using FABulous framework:

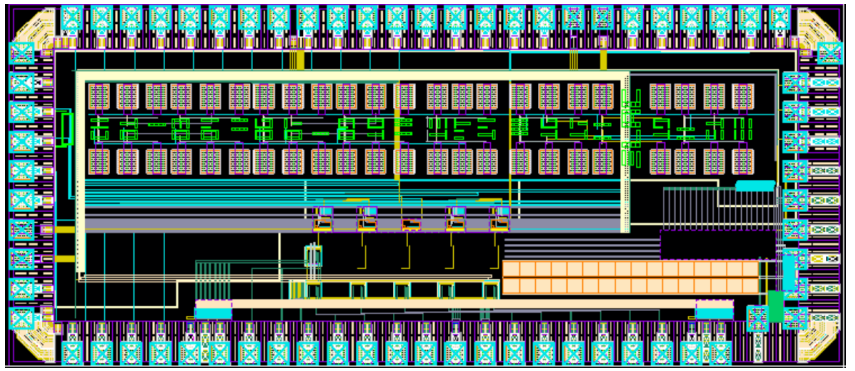
2nd Generation Development: ASIC+eFPGA functionality demonstrated (TSMC 28nm)



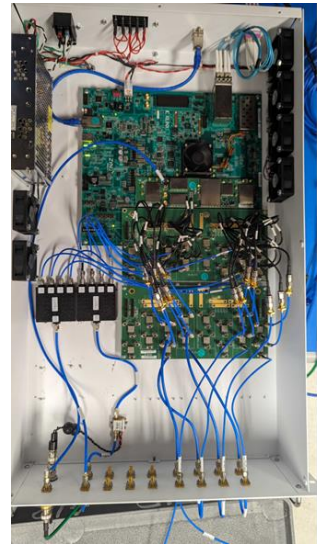
Fabulous v2 ASIC
(1mm x 1mm)

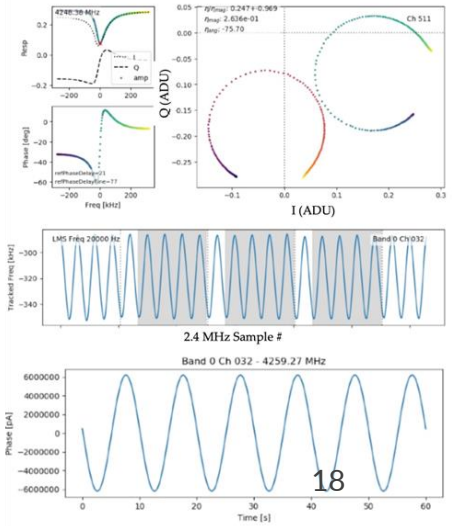
Outputs from eFPGA (16b counter) probed with oscilloscope

Precision timing for 4D tracking and Calorimetry: 28nm chip containing 6.25ps high-precision time-to-digital converters and custom delay-line test devices submitted at the end of January



Qubit-based Sensor Readout for Dark Matter Search: SLAC digital RF platform demonstrated successful readout of superconducting quantum-based sensor for dark matter search





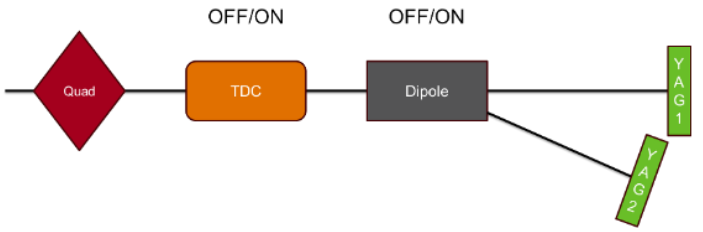
Beam Physics & Modeling Progress: Generative Phase Space Reconstruction (GPSR)

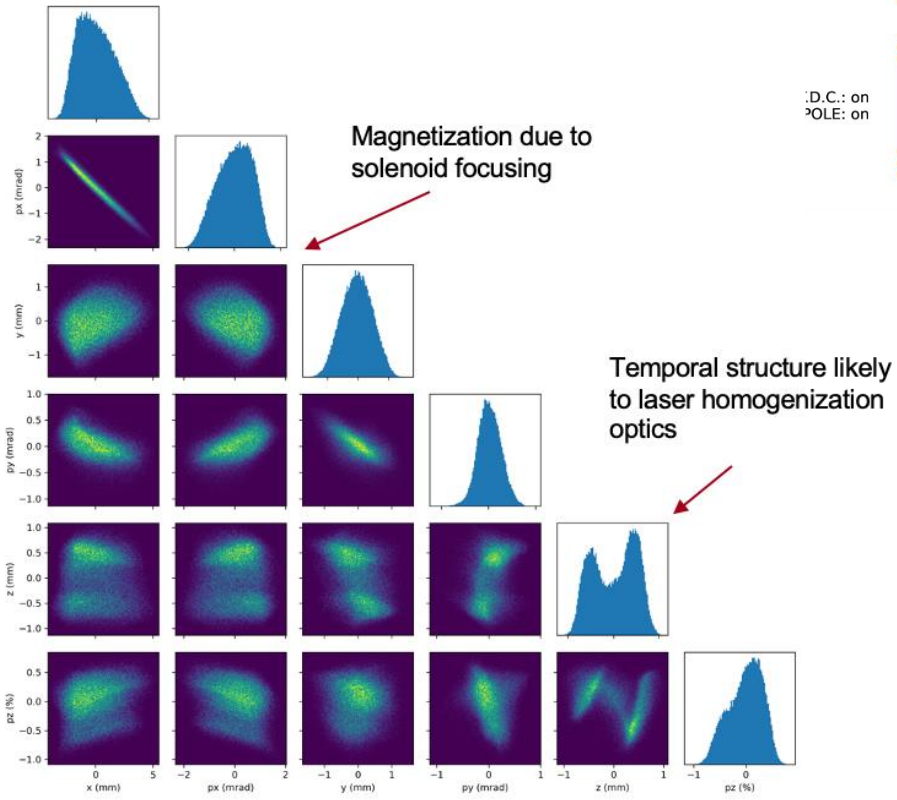
- In FY'23 developed a **novel method to reconstruct high-dimensional phase space distributions using generative machine learning and backward differentiable physics simulation** and experimentally demonstrated detailed, fast reconstruction of 4D phase space, with very few measurements required.

- Have now extended this to an experimental demonstration of 6D phase space reconstruction, with >100x faster measurement and reconstruction than existing methods.

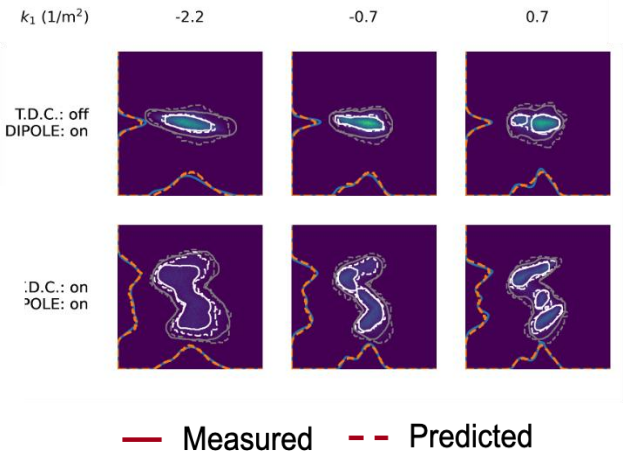
- Worked with collaborators to validate the method for characterization of flat beams [Kim, et al., arXiv:2402.18244], showing detailed reconstruction and good agreement with bulk scalar emittance metrics derived from standard methods.

- Ryan Roussel applying for HEP ECA this year to develop the GPSR method for more challenging use cases and heterogeneous diagnostics.





Agreement between predictions and measurements on downstream screen



Reconstructed 6D distribution at AWA

Measurement: ~8 mins
Training: ~8 mins

SRF Gun R&D at MSU

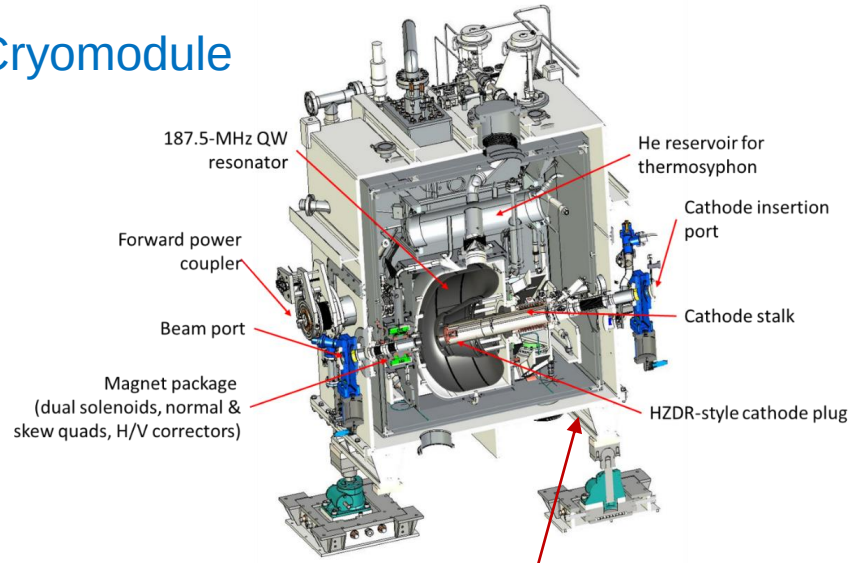
Scope

- Design and construct a SRF quarter-wave cavity and cryomodule including a SC solenoid magnet
- Develop cathode manipulator-stalk system and test gun cryomodule using a metal cathode (no beam)

Blank Cavity Test

Parameter	Requirement	Measurement
4.4 K Q_0 at nominal field	> 1.0×10^9	1.7×10^9
Surface E_{peak}	> 34 MV/m	40 MV/m
FPC Q_{ext} Setting	1.0×10^7	3.0×10^{7}*
Input Power at 30 MV/m	625	208*
Microphonics amplitude over 4 hours	< 19 Hz	1σ = 4.2 Hz
Q_{ext} of cavity probe	> 2×10^{11}	5×10^{11}
FPC DC bias voltage		1 kV
Tuner Range at RT	+6/−15 mm	Stroke > 21 mm
Slow tuning range	60 kHz	60 kHz

Gun Cryomodule



Integrated Test Setup: FPC, Tuner, Cryostat Assembly

Amazing things happen at SLAC every day

PRESS RELEASE

SLAC completes construction of the largest digital camera ever built for astronomy →

Once set in place atop a telescope in Chile, the 3,200-megapixel LSST Camera will help researchers better understand dark matter, dark energy and other...

April 3, 2024 · 10 min r

PRESS RELEASE

SLAC fires up the world's most powerful X-ray laser: LCLS-II ushers in a new era of science →

With up to a million X-ray flashes per second, 8,000 times more than its predecessor, it transforms the ability of scientists to explore atomic-scale...

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SLAC TODAY

CALENDAR NEWS STAFF RESOURCES

New digital library provides tools for STEM outreach

From STEM Outreach & Events

March 28, 2024

EMAIL | PRINT

A new resource called the STEM Library is now available to support your STEM outreach efforts. It's brought to you by the STEM Outreach & Events team, who's curated a variety of educational materials for your own use.

STEM Library homepage

What's it for?

The digital library holds STEM educational, outreach and engagement resources. Right now, the library's in a pilot stage, as the majority of these resources are geared toward K-12 activities which you can browse by age, type and topic. They include science demonstrations, DIY projects and crafts using ordinary household items.

You may have seen some of these activities at one of our many outreach events at the lab, like Family Day. Now, you can take these ideas home to your families and communities for use at science fairs, summer camps and similar events.

As the library grows, we'll expand our coverage. If you'd like to submit a suggestion for a STEM activity, complete this form.

Connect with us

Join the #stem_outreach Slack channel for STEM-related info. You can share an idea, get help planning an activity or learn about a volunteer opportunity, among other things. All employees are welcome.

March 12, 2024

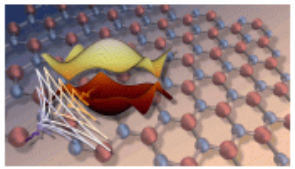
A newly published protein structure helps explain how some anti-cancer immunotherapy treatments work

Scientists at Stanford and NYU have published and investigated a new structure of the protein LAG-3 which could enable the development of new cancer treatments.

April 18, 2024

Symmetry: Physics vocabulary, AI edition

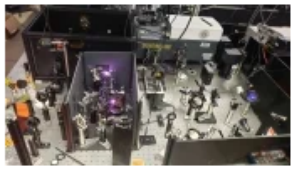
Do you know your convolutional neural networks from your boosted decision trees?



April 15, 2024

Researchers control quantum properties of 2D materials with tailored light

The team developed a groundbreaking method that harnesses the structure of light to twist and tweak the properties of quantum materials.



February 15, 2024

A battery's hopping ions remember where they've been

Seen in atomic detail, the seemingly smooth flow of ions through a battery's electrolyte is a lot more complicated.