

DOE High Energy Physics Advisory Panel (HEPAP) Meeting
December 5-6, 2024



Test Beam Facilities for Particle Accelerator Development

Mark Palmer

Chair, BNL Accelerator Science & Technology Department

December 5, 2024

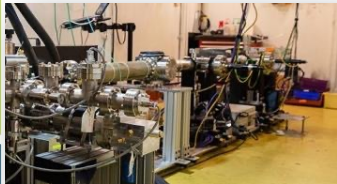


Outline

- Accelerator facilities and needs for test beams
- Test Beam Facilities across the DOE-SC laboratories
- Access Mechanisms
- Conclusion

Acknowledgements to the staff of each of the facilities discussed here...

DOE Operates 17 National Laboratories → 10 by the Office of Science → 12 Accelerator-based DOE-SC National User Facilities



LCLS MeV-UED



Fermilab Accelerator Complex



Spallation Neutron Source



Advanced Light Source



Advanced Photon Source



Relativistic Heavy Ion Collider → EIC



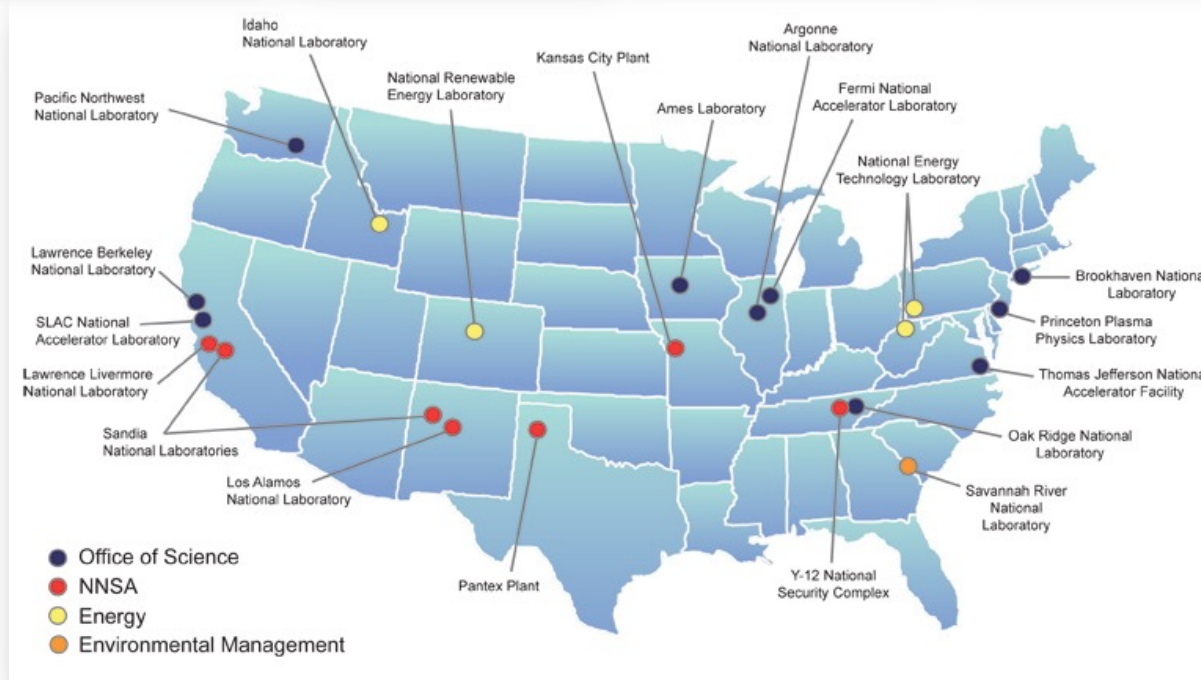
Linac Coherent Light Source + LCLS-II



FACET-II Beam Test Facility



Stanford Synchrotron Radiation Light Source



Accelerator Test Facility



National Synchrotron Light Source II

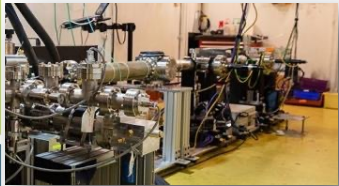


Continuous Electron Beam Accelerator Facility

Access to these DOE National User Facilities is made for academic R&D on a competitive basis at no cost to the user

Test Beam Facilities for Particle Accelerator Development - HEPAP, Dec 5-6, 2024

DOE Operates 17 National Laboratories → 10 by the Office of Science → 12 Accelerator-based DOE-SC National User Facilities



LCLS MeV-UED



Fermilab Accelerator Complex



Spallation Neutron Source



Advanced Light Source



Advanced Photon Source



Relativistic Heavy Ion Collider → FIC



Linac Coherent Light Source + LCLS-II



FACET-II Beam Test Facility



Stanford Synchrotron Radiation Light Source

2 of these National User Facilities focus on **development of accelerator concepts** and help **train the accelerator workforce**:

- **ATF:** ARDAP Accelerator Stewardship Program
- **FACET-II:** GARD Advanced Accelerator Concepts



Accelerator Test Facility



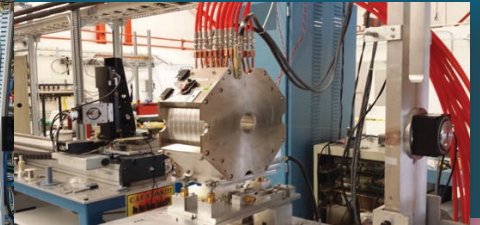
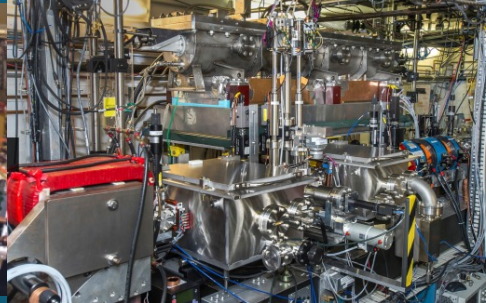
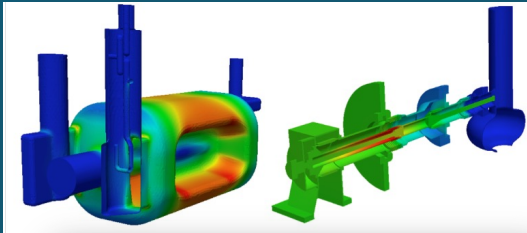
National Synchrotron Light Source II



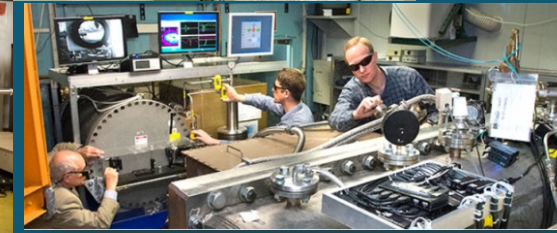
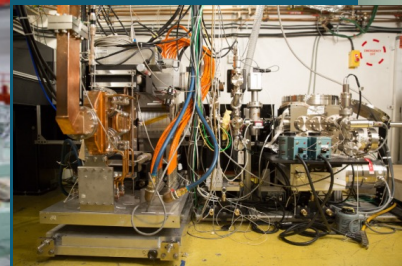
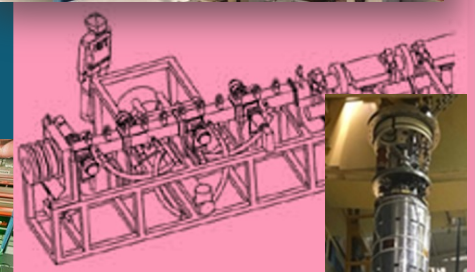
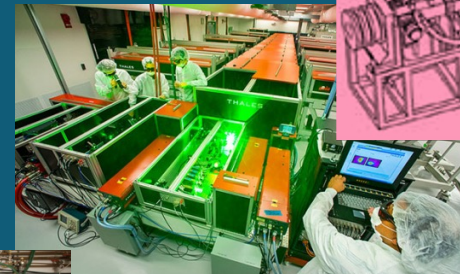
Continuous Electron Beam Accelerator Facility

Access to these DOE National User Facilities is made for academic R&D on a competitive basis at no cost to the user
Test Beam Facilities for Particle Accelerator Development - HEPAP, Dec 5-6, 2024

Building National User Facilities requires developing the accelerator technology and underlying science



Over 50 specialized accelerator
R&D Capabilities exist
across the DOE Office
of Science complex



Test Beam Facilities for Particle Accelerator Development - HEPAP, Dec 5-6, 2024

Test Beam Capabilities

- Maintaining and updating the DOE Accelerator Complex requires test beams to:
 - Maintain and improve existing accelerator capabilities
 - Develop new capabilities
 - Design next-generation facilities
 - Train a new generation of accelerator specialists
- Overview of Test Beam Capabilities
 - Utilize 3 facility classifications in the following slides
 - Will focus on those operated through DOE-SC
 - Not NNSA capabilities (eg, LANL)
 - Not university

SC User Facility

Collaborative R&D

Facility Research+

DOE-SC Test Beam Capabilities

Collaborative R&D

Argonne National Laboratory:
Argonne Wakefield Accelerator (AWA)

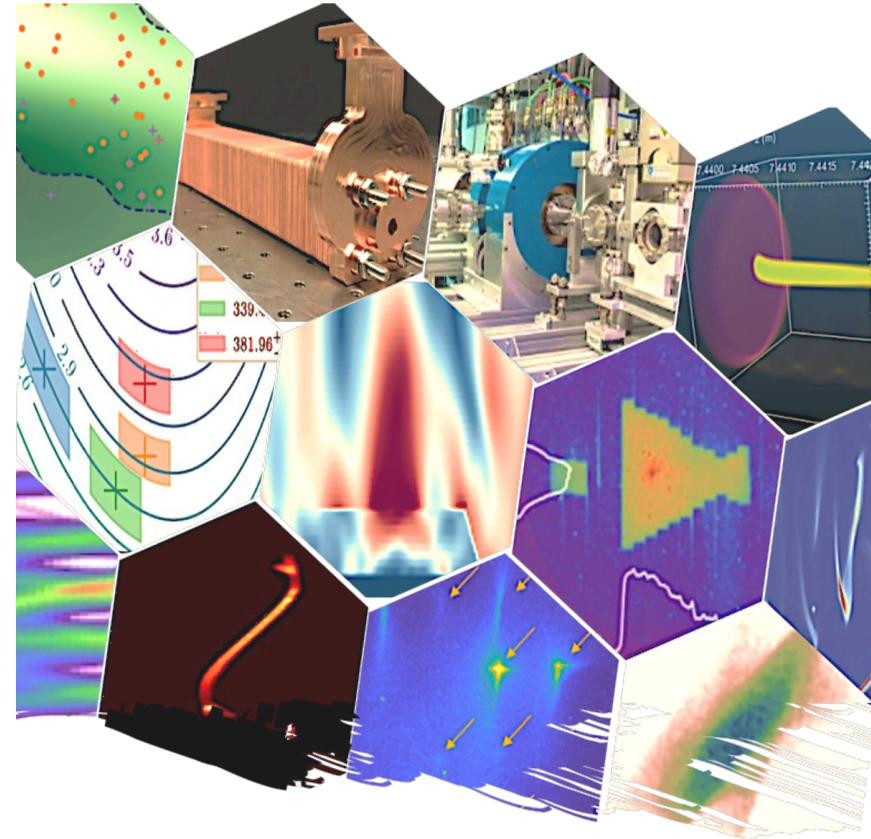
Core Thrusts:

- **Advanced Acceleration:** high-gradient high efficiency acceleration
- **Beam production:** brightness & high charge
- **Beam manipulation & diagnostics:** shaped-beam distribution, emittance control and repartitioning

Research program driven by external collaborations:

University, lab, industry, projects...

Program: GARD Advanced Concepts



DOE-SC Test Beam Capabilities

Brookhaven National Laboratory:
Accelerator Test Facility (ATF)

SC User Facility

Core Thrusts:

- Novel particle acceleration techniques
- Beam instrumentation & manipulation
- High-brightness radiation sources
- Ion generation and acceleration
- Mid- and Long-wave infrared laser development

Targets broad accelerator S&T support for basic science, security, industry, and medical applications

Program: ARDAP Accelerator Stewardship

BNL MeV-UED

Collaborative R&D

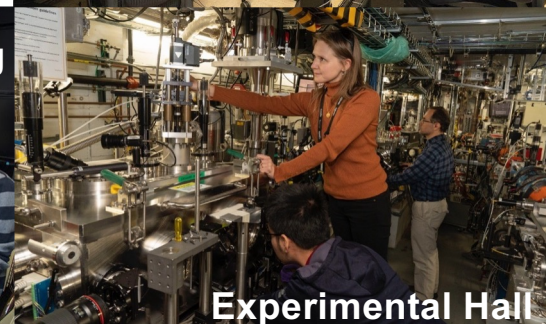
- Low energy accelerator development (UED, UEM, specialized irradiation, etc)



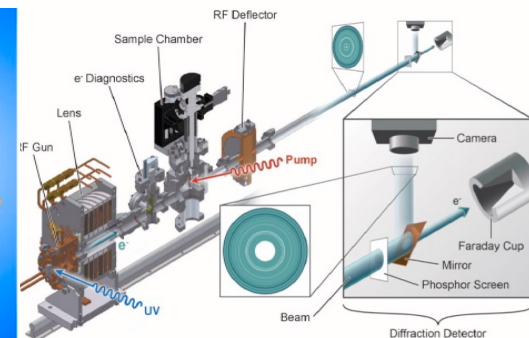
Control Room



Training



Experimental Hall



Test Beam Facilities for Particle Accelerator Development - HEPAP, Dec 5-6, 2024

DOE-SC Test Beam Capabilities

Fermilab:
FAST and IOTA

Collaborative R&D

Facility Research+

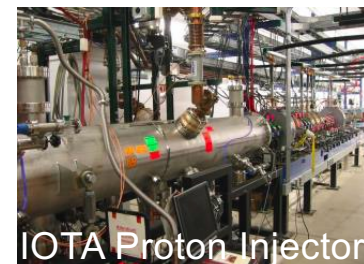
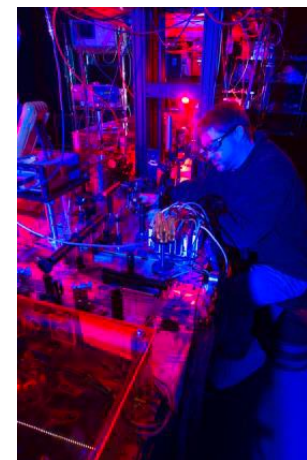
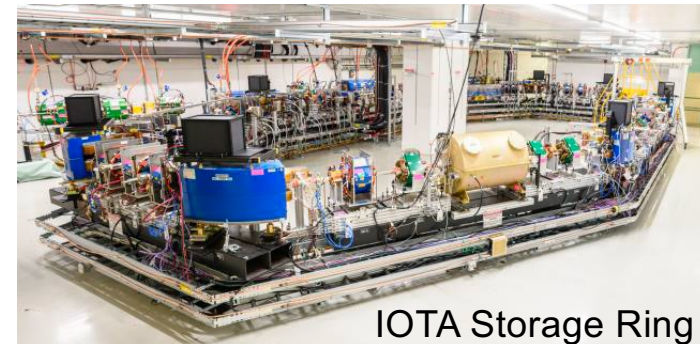
Core Thrusts:

- Frontier R&D topics identified as part of the GARD Accelerator & Beam Physics thrust
- HEP intensity-frontier accelerator R&D
- R&D for concepts and technologies needed for Fermilab's future accelerator complex
 - Increasing the beam intensity achievable in future HEP machines
 - AI/ML-driven controls for autonomous facility operations

Program: GARD Advanced Concepts



Test Beam Facilities for Particle Accelerator Development - HEPAP, Dec 5-6, 2024



DOE-SC Test Beam Capabilities

Jefferson Laboratory:
Upgraded Injector Test Facility

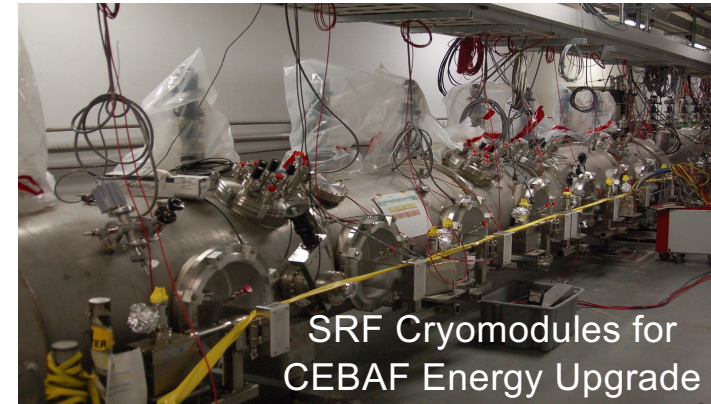
Facility Research+

Collaborative R&D

Core Thrusts:

- Tests of new accelerator technologies
 - Cryomodules
 - RF cavities
 - Photocathodes
 - Polarimeters
- Venue for low energy physics experiments with polarized electron beams

Program: NP



DOE-SC Test Beam Capabilities

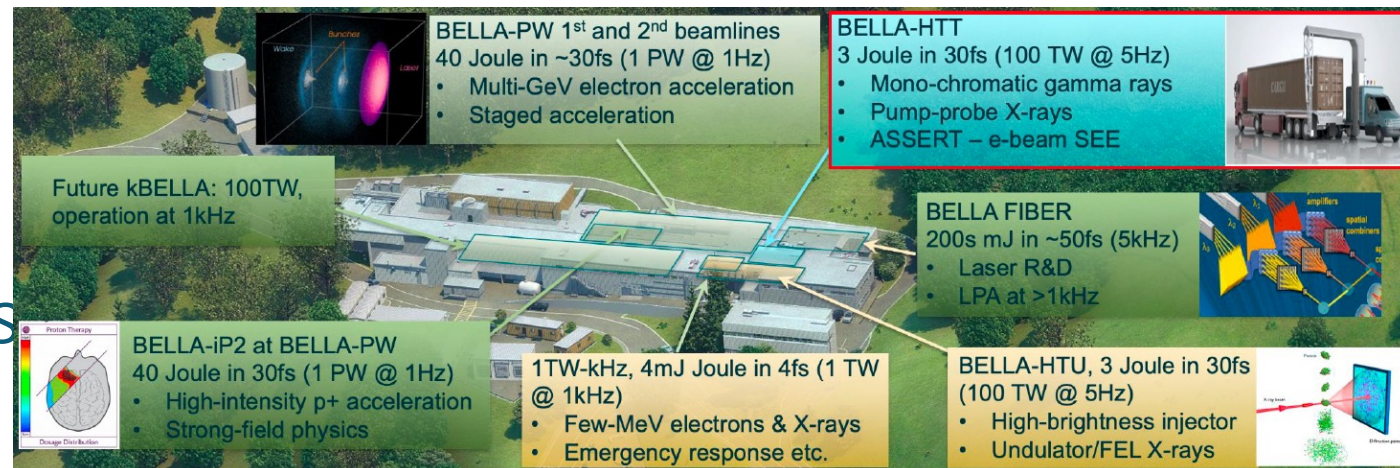
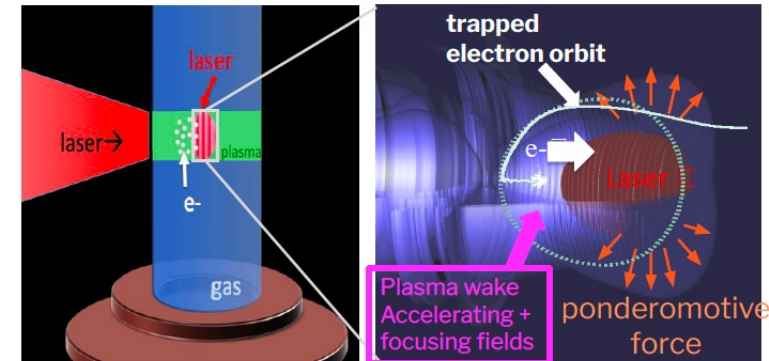
Lawrence Berkeley National Laboratory:
BELLA Center

Collaborative R&D

Core Thrusts:

- Laser Wakefield Acceleration
- Application Development
 - Compact Radiation Sources
 - Plasma Science
 - Ion acceleration
 - HEP applications development
 - Laser Technology
 - Strong-field QED

Program: GARD
Advanced Concepts
Also *FES LaserNetUS*
and other...



Test Beam Facilities for Particle Accelerator Development - HEPAP, Dec 5-6, 2024

DOE-SC Test Beam Capabilities

Oak Ridge National Laboratory:
Beam Test Facility (BTF)

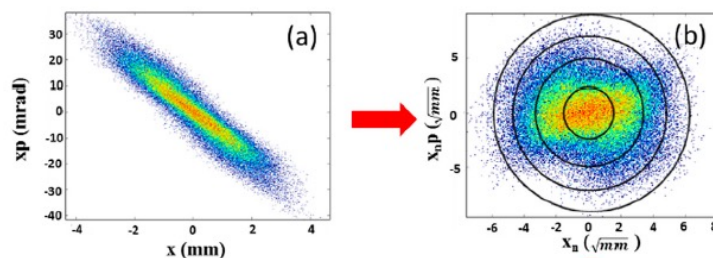
Facility Research+

Collaborative R&D

Core Thrusts:

- Optimization of Spallation Neutron Source systems performance
- Well instrumented beamline that can support unique high intensity beam R&D

Program: BES



Characterization of Beam Phase Space

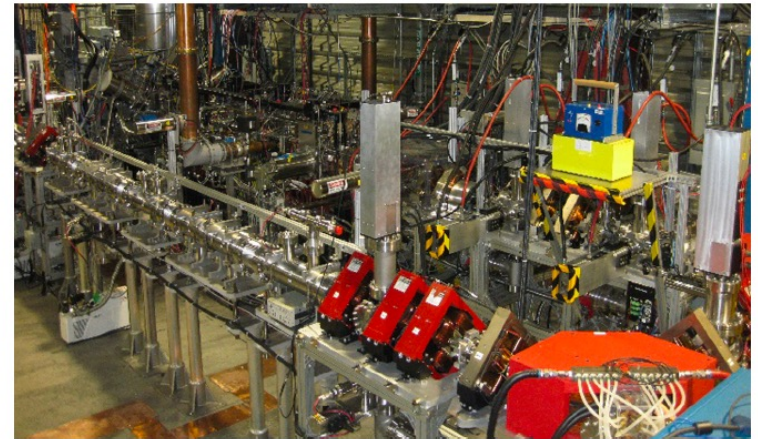
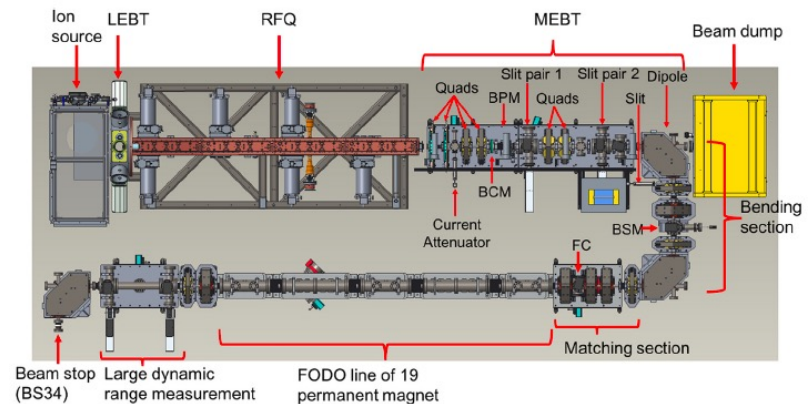


Fig. 1. A photograph of the final BTF beam line at SNS.



DOE-SC Test Beam Capabilities

SLAC National Accelerator Laboratory:
FACET-II

Core Thrusts:

SC User Facility

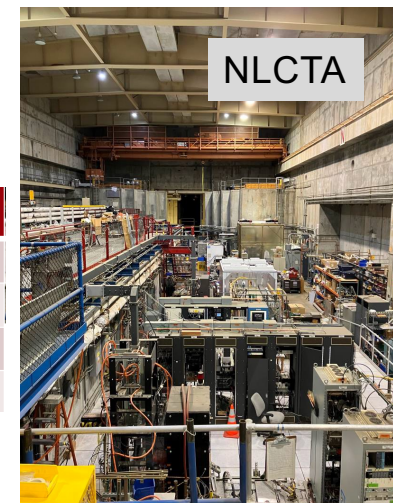
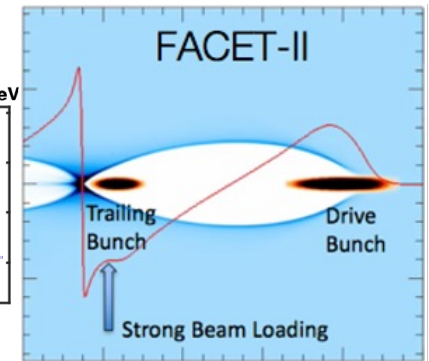
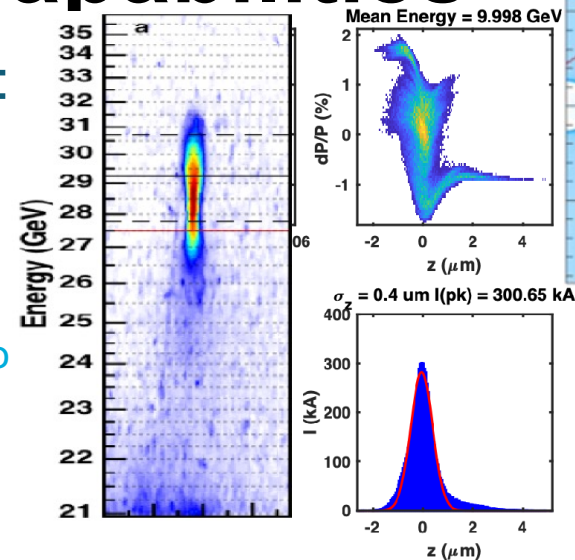
- SC User Facility for Beam-driven plasma wakefield accelerator research
- Beam quality in plasma wakefield accelerator
- Generation of beams with unprecedented brightness
- Novel research
 - Bright gamma-ray bursts
 - Study SFQED phenomena
- Creating ML/AI based virtual diagnostics for extreme beams

Program: GARD Advanced Concepts

SLAC NLCTA

Collaborative R&D

- RF Test Capabilities (S- and X-band)
- Support for novel beam development (e.g. cold copper technology, new RF concepts, etc)



Test Stand	Klystron	SLED-II	Pulse length	Typical power
S	S-band 5045	No	2 μs	10 MW
X0	X-band XL-4	No	1 μs	10 MW
X2	X-band XL-4	Yes	160 ns (compressed)	130 MW
X3	X-band XL-4	Yes	200 ns (compressed)	30 MW

Access to Test Beam Capabilities

- SC User Facility process for 2 of the above
- Collaborative development for the others
- And a new access model:
 - 2025 is the pilot year

<https://www.beamnetus.org>



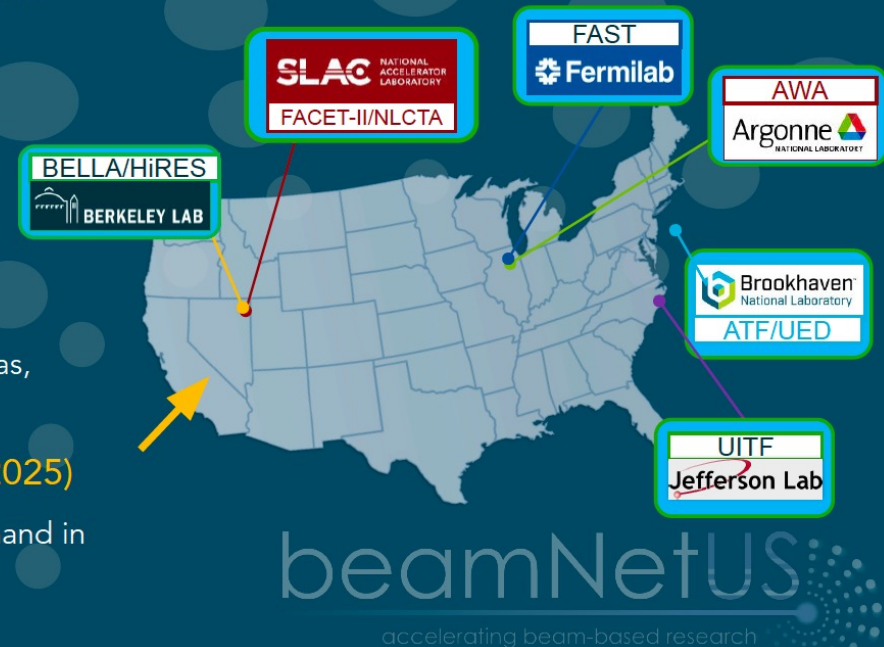
What is BeamNetUS?

A network of facilities united in a common mission:

- ❖ Advance accelerator research and applications of accelerator technology
- ❖ Provide access to unique accelerator facilities and specialized equipment
- ❖ Foster collaboration to exchange ideas, skills and resources.

Facilities involved in Pilot Year (2025)

- ❖ Network will grow according to demand in subsequent years



Conclusion

Test Beam Facilities for accelerators provide:

- Foundation for the continued evolution of key accelerator physics concepts and technologies
- Testing capabilities for sub-systems required for our operating facilities
- Resources for academia and industry
- Training ground for the next generation of accelerator specialists

Challenges:

- Capital and operating costs are not small
- Alignment with near-, mid- and long-term needs of the science community (also with non-science users of these capabilities)
- Not all types of beams that are potentially of interest to the HEP community are represented
- How do we prioritize our accelerator R&D facility investments to ensure that the next generation of capabilities are available when needed?